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ELEMENTS OF GEOLOGY,

FOR THE

USE OF SCHOOLS.

BY WM. W. MATHER.

PUBLISHED BY WILLIAM LESTER, JR.

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1833.

DISTRICT OF CONNECTICUT, ss.

Be it remembered, that on the 27th day of August, A. D. 1833, William Lester, Jr. of the said District, hath deposited in this office the title of a book; the title of which is in the words following, to wit:—" Elements of Geology, for the use of Schools, by Wm. W. Mather," the right whereof he claims, as Proprietor, in conformity with an act of Congress, entitled " An act to amend the several acts respecting copy rights."

CHAS. A. INGERSOLL,
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211362

PREFACE.

THE object of the following pages, is, to exhibit a concise sketch of Geology for the use of Academies and the higher classes in primary schools. It is desirable that the community should be familiar with the leading facts of this science, that they may be enabled to apply them to the various economical purposes of life. Every science is valuable to the community, in proportion as the knowledge of its facts and applications, is disseminated among the mass of the people. As the number of observers increases, more facts will be accumulated, and the resources of the country developed.

Young men preparing for college should acquire a knowledge of the elementary principles of geology; and in their collegiate course, the study might then be carried much farther than it is at present. Independent of the practical utility of this science, it furnishes a constant source of amusement, or pleasant occupation, in journeying over tracts of country that would otherwise be perfectly uninteresting. It even offers an inducement for the exercise of walking and traveling, to those who would otherwise be too sedentary in their habits.

In the arrangement of the subjects, Bakewell's Geology has been followed with few exceptions. The works employed in the compilation of this work were Bakewell's Geology, edited by Professor Silliman; Conybeare & Phillips' Geology; De La Beche's Geology; Eaton's Geological Text Book; Cleaveland's Geology; Greenough's Geology; Silliman's Journal; Journal of the Academy of Nat. Sciences of Philadelphia; Annals of the Lyceum of Nat. History of New York; Maclure's Geology; American Philosophical Transactions; Philosophical Transactions of the Royal Society of London; Journal of the Royal Institution of Great Britain, and Edinburgh Journal of Science. When quotations are made without reference, they are from the American edition of Bakewell's Geology, edited by Professor Silliman, and containing a sketch of his course of Lectures in Yale College. The author has introduced some things, for which he alone is responsible, and derived from his own observation. The organic contents of the "superior rocks" have been but casually touched upon, as a more extended course is required, to enable one to distinguish strata by their organic remains.

This little work is a sketch of the author's public course of instruction in geology; during the progress of which, its principles are illustrated by references to American localities, and by visiting those localities when practicable.

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SKETCH OF THE HISTORY OF GEOLOG

Ancients speculated on subjects connected with g
logy. Geology made little progress until the latter p
of the eighteenth century. Most of the facts of geolo
have been collected since the beginning of the ninetee
century. William Smith's geological maps. Geo
gists of England, France, Germany, and the Uni
States. Progress of American geology. . . . .]

INTRODUCTION.

GEOGRAPHY is a description of the Earth, or it is a science that teaches the positions of all the regions of the earth, with regard to each other, and describes the principal objects they contain. Many of the sciences group themselves around Geography, and yield to it, and to each other, a mutual support.

Geography is now considered in a more enlarged sense than it was originally. It now comprehends four great divisions, viz:

1. Mathematical geography occupies itself in measurements of the earth's surface, and in ascertaining the location of places, with reference to certain fixed lines, or lines of latitude and longitude.

2. Historical geography consists in noting the times of particular events, and the places and circumstances of their occurrence.

3. Political geography describes the earth in its relations with men.

4. Physical geography is a branch of geography which is freed from the limitation of kingdoms and empires, and all artificial divisions. It embraces the natural history of the earth,—all objects that can be represented by geographical maps, and every thing, depending on causes, which may have concurred, at different times, in the actual constitution of the earth.

Physical geography includes GEOLOGY; a science that has for its object the examination of the structure of the earth, the manner in which all the materials forming it are arranged with regard to each other, and the action of

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QUESTIONS ON THE INTRODUCTION TO GEOLOGY.

What is geography? What does geography now comprehend? What is mathematical geography? What is historical geography? What is political geography? What is physical geography? or what does it embrace? What is geology?

frosts, rains, floods, tides, winds, earthquakes and volcanoes, in effecting changes upon its surface. The study of geology leads us to examine and reflect upon the works of nature that we see every where scattered around us, and it reveals to us the history of the great convulsions and revolutions that the earth has experienced at remote periods of time. The question, "*What is the earth made of?*" has probably presented itself to every mind, and this question, under certain limitations, includes most of the objects of geology, viz: "What are the substances of which the earth is composed? What is the order in which they are arranged? What are the changes which they appear to have undergone?"

Fact If at any point of the earth's surface we examine the substances composing it, we find that they are either clay, sand, gravel, rock, or various mixtures of these, and that if rock be not found at the surface, it may be by digging to some depth below, and that below this, the solid rock continues as far as the power of man has hitherto enabled him to penetrate.

When we slightly examine the surface of the earth, every thing seems without regularity; but by close observation, we see that the rocky, as well as the earthy materials exposed to our view, are not all alike, but differ much in their appearance, properties and composition, and that these rocks are arranged in a regular order one over the other. The rocks and other earthy bodies are composed of minerals. Sometimes a single kind of mineral forms the masses of sand, clay or rock; but more often, two or more mineral substances are aggregated to form those bodies.

Minerals, are those bodies found in or upon the earth, that are not animal or vegetable productions. There are

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What does geology lead us to examine? What does it reveal to us? What are the principal subjects of geological enquiry? Of what materials do we find the earth composed? Does the solid rock always occur within a moderate depth from the surface? and how far does it continue? Of what are the rocks composed? What are minerals?

only ten that occur in such abundance as to form the proper constituent parts of rocks, and these are by Professor Eaton called the geological alphabet.

They are

QUARTZ;
FELDSPAR;
MICA;
HORNBLENDE;
AUGITE;
CHLORITE;
TALC;
GYPSUM;
LIMESTONE;
SERPENTINE.

The other minerals are found in veins, which appear to have been once open fissures in the rock, and since filled with mineral matter; or in beds which are isolated masses of mineral, imbedded in other rocks; or else they are disseminated, or scattered irregularly in the rocks in small grains and masses.

Certain mineral substances are found almost constantly associated with certain others, so that if one be found in any particular situation, the others may be expected to be found by searching for them. Salt, and salt water, for instance, are almost always found in connection with clay and gypsum; lead ores with those of zinc; tin ores with those of tungsten and with topaz.

Rocks are the aggregates of grains or pieces of one or more minerals, adhering to each other so as to form masses.

The grains of minerals are so small in some rocks, as not to be distinguished from each other, and then these rocks are said to be *compact*. When the grains are distinguishable from their magnitude, the rock is said to be *granular* in its structure. When the parts composing the rocks shew plane and brilliant surfaces on being

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How many and what minerals form the rocks? Where do the other minerals occur? What are veins? and what beds? When are minerals disseminated? Do particular minerals almost constantly accompany each other? What minerals accompany salt and salt water? What ores are associated with the lead ores? What ores and mineral with tin ores? What are rocks? When are they compact? when granular? and when crystalline?

broken, they are said to be *crystalline.* The c grained limestones are generally instances of the comp structure. Common sandstone shews the granular; the white marbles and granite the crystalline structu Rocks are said to be slaty, or to have a slaty structı when they split out in thin layers like common slate roofing, or drawing slate.

The mean density* of the earth is about five tii [redacted] than water; and as the mean density or spe gravity of the mass of materials at, and near, the surf of the earth, is only two and a half, it follows, that mean density at some distance below, is greater than and near its surface.

There are certain phenomena, which seem to indic that the mass of the earth at some distance below surface, must be in a liquid or melted state.

1. The earth has the exact form that a fluid b would assume, moving as the earth does.

2. The earth loses more *caloric*† than it receives the course of a year, and sufficient to melt several fee depth of snow over its whole surface. This would i cate, that it is a gradually cooling mass.

3. The rapidity with which motion is communic over extensive portions of the earth during earthqu is somewhat like the ground swell, felt on the ocean on floating icefields, hours before any motion of the perceived.

What rocks are instances of the compact, gra and crystalline structures? What is the slaty ture? What is the mean density of the earth? is the mean density of the bodies near the surfac earth? What results from this difference? phenomena seem to indicate that the earth may at a considerable depth below the surface?

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* The density and specific gravity are synonymous, mean the relative weight of a body, when compared wit bulk of water.

† Carloric is that which enters into a body when he *passes off* when cooling. Heat is a term applied to th *we perceive in* touching a hot body.

4. The occasional simultaneous action of volcanoes, far distant from each other.

5. After going 50 or 60 feet below the surface of the earth, the heat increases according to the depth, from one to two degrees of Farenheit's thermometer for every 100 feet. The warmth of the earth below the surface is variable from 30 to 60 feet, in consequence of the variation of the seasons, and the filtering of rain and spring water through the ground; but below that, the temperature is uniform from season to season, and warmer as you descend farther. In the caves under the city of Paris, the thermometer does not shew a variation of one-tenth of a degree of Farenheit's thermometer from one year's end to another.

If the temperature increases with the same rapidity to the centre of the earth, as it does for 2000 feet from the surface, the heat, from 30 to 60 miles below, would be sufficient to melt the most refractory rocks.

It is only the crust of the globe that comes under our direct observation, and it is to this, that geology more particularly confines itself.

In speaking of the *crust of the globe*, it is not meant to convey an idea that the earth is hollow, or in a fluid state, but that the part coming under our observation is analogous to a thin crust or rind, in comparison with the mass of the earth. The greatest depth to which man has penetrated is less than 3000 feet, and the highest mountains, the Himalaya, are less than 27,000, so that not more than 30,000 feet from the surface towards the centre, is exposed

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How far below the surface is the temperature variable from the effects of the seasons, springs &c.? Below that depth does the temperature vary at any particular place? As you descend deeper does the temperature diminish or increase? Should the temperature increase at the rate observed, at what depth would the heat be sufficient to melt the rocks? What part of the Earth comes under our observation? What is meant in speaking of the crust of the globe? To what depth has man penetrated into the Earth? How high are the highest mountains on the globe?

to our observation. 30,000 feet is about one-seven hundredth part of the distance from the surface to the centre.

This portion of the earth exposed to our observation, bears no more proportion to the magnitude of the globe, than does the thin coat of varnish on an artificial globe to its mass. The most elevated mountains, may be compared to the dust collected on a school globe; and the great mountain chains to fibres of silk stretched across its surface.

Such views shew the insignificance of man when compared with the stupendous works of our Creator; and we may well exclaim with the Psalmist: "What is man that thou art mindful of him."—*Ps.* viii. 4.

How does the whole thickness that we can examine, compare with the whole Earth? To what may the mountains and mountain chains be compared?

ELEMENTS OF GEOLOGY.

CHAP. I.

THE proper foundation of Geology, as a science, was laid by a German, of the name of Lehman. He observed that although there were many kinds of rock, they could all be referred to two general classes. He likewise observed that the lowest rocks exposed to our observation were more or less crystalline in their structure, and contained no traces of the remains of plants or animals; while the rocks lying over the latter were generally compact, slaty, or granular, and abounded in the remains of marine animals, such as various shells and bones, or with plants, as the ferns and reeds. From the circumstances of their different structure, and from one containing organic remains, or remains of animals and plants, he inferred, that the lower rocks containing *no* organic remains, were formed *first*, from which circumstance he called them *primary* or *primitive rocks;* and the others lying upon the primary, and containing organic remains, he called *secondary*

By whom was the foundation of Geology laid? What did he observe as to the kinds of rock? What was the structure of the lower rocks? What was the structure of the upper rocks? What were found in the upper that were not in the lower rocks? From the organic remains found in the upper rocks, what conclusion was drawn as to the relative ages of the upper and lower rocks? What were the upper or fossiliferous rocks called? What are organic remains or fossils? What are petrifactions?

rocks. The remains of animals and plants, naturally enclosed in the rocks, clays, &c. are called *organic remains*, because they are the remains of organic bodies; they are also called fossils; and when the organic substance is changed into stony matter, they are called petrifactions.

The ocean has not always been confined to its present bed, for, rocks composed mostly of the remains of various marine animals, are found in almost every country. The rocks containing these remains are not confined to detached masses, but often form extensive layers, or strata, as they are called, of many miles, and often, many hundreds of miles in extent. They not only occur in valleys, but they cap the highest mountains, and their thickness varies from a few inches to several hundred feet. Nearly all the organic remains, being those of animals calculated only for living in water, the sea must, at some time, have covered all the land for a considerable period. We see, then, that the relative levels of the continents and ocean must have changed; and one of two conclusions follows, viz: that the ocean has fallen below its former level and exposed the dry land, or, that the continents have been raised and made to emerge from the ocean.

We find the remains of animals and plants imbedded in the rocks, not only near the surface of the earth, but at the depth of hundreds and even thousands of feet. An-

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Has the ocean been always confined to its present bed? And what evidence is there that it has covered all the and? Do the rocks containing organic remains occur abundantly in almost every country? And do they occur of any great extent and thickness?

Were the animals, whose remains are found, adapted for living in water or on land? From observing that rocks filled with the marine animals are abundant over a large portion of the earth, what conclusion follows? Are the organic remains imbedded in the rocks near the surface only? Are they of every kind, jumbled indiscriminately together? And how are they arranged?

other point deserves attention, viz: that these organic remains are not of every kind jumbled together, but that particular species belong to particular strata, where, in general, they appear to have grown, died, and been imbedded. Many of the rocks are several hundred feet in thickness, and the strata of each exhibit distinct species and genera of animals. The animals cannot have penetrated through the vast masses under which they are entombed, and the succession of different animals shews, that the strata must have been formed in succession, and each, must at some time have been the uppermost stratum, in, and upon which the animals were deposited, and afterwards covered by succeeding strata. In the lower secondary rocks, the organic remains are almost entirely different from the existing genera and species of animals and plants; and in proportion as the rocks are of more recent origin, lying successively upon the lower ones, the fossils approach more and more nearly to the animals and plants in existence. The fossil remains of animals, not now in existence, entombed in the solid rocks, present us with durable monuments of the great revolutions which the earth has undergone at remote periods of time, and open to us a new page for our study and investigation in the great book of nature.

The period of time required to produce the effects observed in the fossiliferous rocks must have been very great. Clearly, that was not a temporary inundation like the deluge, the evidences of which we see every where on the surface of the earth; but, it would seem, must have

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Do the animals appear to have penetrated through the masses under which they are found? And what does the succession of different animals in the different strata shew? Are the animals in the lower secondary rocks, similar to those now existing? In the most recent rocks do the organic remains approach more nearly to the animals and plants now existing. What do the fossil remains shew us? Does any great period of time appear to have been required to produce the observed results? Do we see evidences of the deluge, as well as of other convulsions and inundations?

continued for almost countless ages. This may at first seem to clash with the Mosaic account of the creation of the world; but instead of that, geology offers incontestible evidence of the truth of the Mosaic account. The *order* which this account assigns to the different epochs of creation, is precisely the same as that, which has been deduced from geological considerations. Geology is a science which has been thought by many persons to draw conclusions at variance with the Book of Genesis; but, "when at last more matured by a series of careful observations and legitimate induction, it teaches us precisely what Moses had taught more than three thousand years ago."

In construing *day*, in the Mosaic account of the creation, periods of time of indefinite duration must be substituted. The reader who may have any doubts upon this interpretation of the term day, is referred to the American Journal of Science, Vol. XXV. pages 30—41, where a full exposition of the terms employed in 1st. of Genesis is given, independent of geological considerations. All geologists, or at least the largest portion of them, admit, that the discoveries of geology are perfectly consistent with the Mosaic History. The following extract from Bakewell's Geology bears in some degree upon the same point.

"The six days in which Creative Energy renovated the globe, and called into existence different classes of animals, will imply six successive epochs, of indefinite duration. The absence of human bones in stratified rocks, or in undisturbed beds of gravel or clay, indicates that man, the most perfect of terrestrial beings, was not created till after those great revolutions, which buried different classes and entire genera of animals, deep under the present surface of the earth. That man is the latest

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From geological phenomena how is the term day explained, as used in the Mosaic account of the creation of the world? Does geology serve to prove any parts of the sacred writings? What geological phenomenon shows that man is the animal last formed upon the earth?

Do the oldest records and traditions prove the same thing?

tenant of the globe, is confirmed by the oldest records or traditions that exist of the origin of the human race.

The great convulsions which have changed the ancient surface of the globe, and reduced it to its present habitable state, were not, it is reasonable to believe, effected by the blind fury of tumultuous and conflicting elements, but were the result of determined laws, directed by the same wisdom which regulates every part of the external universe. Compared with the ephemeral existence of man on the earth, the epochs of these changes may appear of almost inconceivable duration; but we are expressly told, that with the Creator a thousand years are as one day, and one day as a thousand years."

CHAP. II.

Every one must have observed that the mineral substances upon the surface of the Earth, differ much in their hardness, weight, colour, and other qualities. The different minerals appear at first so numerous as to make it difficult to become familiar with them, but on examination it is found, that the number of minerals is not very great, and the elementary substances composing them still less. The bodies called elementary or simple bodies, are those that have never as yet been decomposed into two or more other bodies, as for instance gold, silver, tin, copper, lead, sulphur, &c.

The whole of the elementary substances forming all the minerals, rocks, plants, animals, and every thing we can see upon or in the earth, is only about fifty.

Do the mineral bodies differ much in their qualities? Do they appear very numerous? and are they as numerous as they appear to be! What are elementary or simple bodies? What is about the number of simple bodies?

The elementary substances entering into combination[*] with each other to form the *principal part* of the mass of the globe, are,

Oxygen.
Chlorine.
Hydrogen.
Silicon.
Carbon.
Sulphur.
Aluminum
Calcium
Magnesium
Potassium
Sodium
Iron

Oxygen is the most common substance existing in combination with other bodies, and is supposed to constitute about one half of the whole weight of the materials on the surface of the globe. By its combination with silicon it forms *silex*, which enters into most of the minerals and rocks in large proportion.

Oxygen combined with hydrogen forms water; with carbon, forms invisible elastic bodies like air, but which if breathed destroy life; with sulphur forms acids,[†] one of which is used in bleaching straw, and which you always smell when sulphur is burnt in the air, another of these acids is called sulphuric acid and oil of vitriol.

Are all substances formed of those few simple bodies? What are the elementary substances that form almost all the mass of the globe as far as we know? Which of these is most common in combination with other bodies? About what proportion of the weight of the bodies of the Earth, is oxygen supposed to constitute? What does it form by combining with silicon? What does it form by uniting with hydrogen? What does it form when combined with carbon? What effect is produced by breathing those compounds? When oxygen unites with sulphur what are found? For what is one of these acids used and what is its odour? What is the other acid called?

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[*] Substances are said to *combine*, when they unite with each other so as to change their properties. Thus potassa or soda, by union with oil or grease, form soap, a substance totally different from the bodies of which it is formed.

[†] Acids are generally sour to the taste, and by their combination with other bodies, they form substances differing both from the acid and the other body.

Oxygen unites with aluminum, calcium, magnesium, potassium, and sodium, which are metals, and forms with the first alumina, which exists abundantly in the clays and slates; with calcium it forms lime, with magnesium magnesia, with potassium potash, and with sodium soda, and with iron it forms the common ores of iron. Oxygen is contained in large proportion in the air, and it is that which supports life by our breathing. It is for want of oxygen that persons die so soon when under water. Most bodies when uniting with oxygen, burn, or give out light and heat.

It is owing to the combination of oxygen with other substances, that oil, tallow, and wood burn.

Oxygen, when free, is a gaseous body; that is, an elastic,* transparent body like air.

When oil, tallow, charcoal or wood are burning, carbonic acid or fixed air is formed, by the combination of carbon and oxygen. Carbonic acid is the gas that causes so many accidents in caves, wells, &c. by people descending into them without proper caution. Being heavier than

When oxygen unites with aluminum, what is formed, and in what does alumina exist abundantly? What are formed by the union of oxygen with calcium, magnesium, potassium, sodium, and with iron? In What is oxygen found in large proportion? What must be in the air, to support life when we breath it? Why is it that persons drown under water? When bodies unite with oxygen, what generally happens? Why is it that oil, tallow, wood, &c. burn when heated in the open air? What is oxygen? What is a gas, or gaseous body? What gas is formed during the burning of wood, oil, tallow, or charcoal? Is this gas heavier than air? Does it ever cause accidents, and of what kind?

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* Bodies are said to be elastic when they can be compressed into a smaller space, and when the pressure is removed, they restore themselves to their original form and bulk. Bodies that are solid may be bent, if longer than broad and thick. If they restore themselves to their first shape they are also said to be elastic.

air, it occupies the lower portion of the well or cave, and as soon as a person is immersed in it, life is destroyed. As a candle or lamp will not burn in it, its presence can be ascertained by lowering a candle into the well, cave or mine. Should the candle not burn freely, it is not safe to enter.

Chlorine and hydrogen are also gaseous bodies, but will not support life.

Chlorine is of a yellowish green colour, and of a peculiar odour. It exists abundantly in combination with sodium to form common salt. Salt is contained in the waters of the ocean, and in such quantity that if separated, it would cover all the land on the globe to the depth of 1800 feet.

La Place estimated the mean depth of the ocean at 10 miles, and from this and the known quantity of salt in the water, the above estimate is made.

Hydrogen gas is the lightest of all known bodies. It has no colour, burns with a hardly visible flame, but gives a great deal of heat, and when this gas is mixed with air or oxygen, and a flame applied, it explodes with great violence, and water is formed. It is used for filling balloons by which men are enabled to ascend many thousands of feet in the air. If a piece of cork be put under water, it rises to the surface, because it is lighter than the water; in the same way, as hydrogen is so much lighter than air, a large bag filled with it, is lighter than the air, and if

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Will a candle burn in it, and how can you ascertain if this gas exists in any situation, and when is it safe to enter a well, cave, &c.? Is chlorine a gas, and will it support life? What is its color, and has it any odour? With what does it exist in combination abundantly? To what depth would the salt of the ocean cover all the land on the globe? Of what is salt composed, besides chlorine? What is the estimated mean depth of the ocean? What is the lightest of all known bodies? Has hydrogen any color, and does it give any light or heat during its burning? When mixed with air or oxygen and inflamed, what effect is produced, and what formed? For what is hydrogen used? Why is it that a balloon filled with hydrogen will rise?

left to itself, rises to a certain height in the atmosphere. A balloon is a ball-shaped bag filled with hydrogen, or with rarified air.

Silicon is a dark coloured substance, burns under certain circumstances, and by its union with oxygen forms silex, which is a white coloured powder. Silex exists pure in rock crystal, and nearly pure in many minerals, as flint, agate, cornelian, jasper, quartz, &c.

Sand is almost entirely composed of silex, and silex forms probably nearly one half of the materials of the crust of the globe.

Silex, when melted with potassa or soda, forms glass, and this is one of the most important uses.

Carbon is the principal substance in all the kinds of mineral coal, in charcoal, and it exists in large proportion in wood, oil, tallow, and all vegetable and animal substances. The diamond is pure carbon. Carbon is black, except when crystallized as in the diamond. Carbon is naturally combined with hydrogen, as in bitumens, oils, &c., with oxygen forming carbonic acid, and with iron forming plumbago or black lead, steel and cast iron. Carbon, and the substances containing it in large proportion, are mostly used for obtaining light and heat, and for reducing the ores of the metals.

Sulphur is a simple body of yellow colour, brittle, without taste, burns easily in the open air, and gives a pecul-

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What is the appearance of silicon, and by its union with oxygen, what is formed? In what does silex exist pure, and in what nearly pure? Of what is sand mostly composed? What proportion of the crust of the Earth is silex? What is silex mostly used for, and how is glass made? In what is carbon the principal substance, and in what does it exist in large proportions? What substance is pure carbon? In what is carbon naturally combined with hydrogen? What are formed by the union of carbon and iron? For what are carbon, and substances containing it in large proportions, employed? What are some of the properties of sulphur?

iar pungent odour. It rarely occurs uncombined with other bodies, except in volcanic countries. It is found united to many of the metals forming ores, and which are called sulphurets. It is used mostly for the manufacture of gunpowder, and sulphuric acid or oil of vitriol.

Iron, combined with oxygen, forms most of the useful ores of iron, but there are few places comparatively, where these ores are found in such quantity as to be valuable.

This combination is more uniformly distributed through the mineral kingdom than any other substance, and it colours almost all minerals. Hardly a fragment of mineral or rock can be selected, that does not contain traces of iron, but generally it is in small quantity.

Oxides are combinations of oxygen with other bodies. The oxides silex, alumina, lime, and magnesia, are called earths, and the two last, alkaline earths. These earths are most abundant in the same order in which they are mentioned, and they constitute at least three fourths of the solid materials upon the surface of the globe.

These substances, by their various combinations with each other, and with other bodies, form a great variety of minerals, and it is not a little remarkable, that those minerâls and substances most useful to man, are most abundant and most uniformly distributed.

Does it occur uncombined with other bodies, and where? When united with the metals, what are formed, and what are they called? For what is sulphur mostly employed? Of what are most of the useful ores of iron composed? Are these found in quantity every where? Is iron almost universally distributed in the mineral kingdom? Does it generally color minerals? What are oxides? What are the most abundant earthy oxides? Which is most abundant? What proportion of the solid materials of the globe do they form? When these substances combine with each other and other bodies, do they form many minerals? Are the most useful minerals the most abundant and widely distributed?

CHAP. III.

It has been remarked that notwithstanding the variety of minerals, those forming the mass of the globe, as far as exposed to our observation, are few in number, viz:

1 Quartz;
2 Feldspar;
3 Mica;
4 Hornblende;
5 Augite;
6 Chlorite;
7 Talc;
8 Gypsum;
9 Limestone;
10 Serpentine.

Slate and clay might be added, but they are rather aggregated minerals, in a minute state of division, than distinct minerals.

Quartz.

Quartz consists entirely of silex. Rock crystal, which is clear transparent quartz, is pure silex. Quartz varies much in its color, but is most generally white or light colored. It is hard, scratches glass, cannot be cut with a knife, strikes fire with steel, cannot be easily melted alone, and when two pieces are rubbed together in the dark they give out light, or phosphoresce, as it is termed, and a peculiar odour is emitted. Quartz, when broken, has a lustre upon the surface like broken glass, but when the quartz is not clear or transparent, the lustre is greasy or looks like a bright surface over which oil had been rubbed.

Quartz is generally in rough, shapeless masses; but sometimes is in beautifully regular forms, more brilliant,

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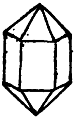
What are the minerals of the geological alphabet? What substances might be added? Of what is quartz composed? What mineral is pure silex? What are the properties of quartz? In what form is quartz generally observed?

and perfect in form, than the lapidary could make them.



These regularly formed bodies, whether they be quartz, or any other mineral, or any substance whatever, are called *crystals*. The usual form under which quartz crystallizes, is a six-sided prism terminated by six-sided pyramids, as seen in the margin.

Quartz occurs compact or solid, when it is said to be massive; and granular, when composed of grains like some of the sandstones. When quartz is very porous it is said to be spongiform; when in pendulous masses like a stalactite or icicle, it is stalactical quartz.

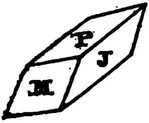
Quartz sometimes forms whole mountains, but more often it is in aggregated masses with other minerals to form rocks. Quartz occurs abundantly on the sea shore, and in the interior of almost every country, in the form of sand. The white pebbles in gravel are quartz, as are most of the hard stones that we see about the country.

FELDSPAR.

There are several varieties of Feldspar, but they agree in some of their more important characters. They are composed of the same ingredients, viz: silica, alumina, and potassa. They are all hard enough to scratch glass, but are less hard than quartz. Feldspar is laminar, or composed of plates, and it has a shining lustre. Its color is variable, but is generally white or reddish. It can be melted without difficulty.

What are crystals? and what is the form in which quartz crystallizes? What is massive quartz? What granular quartz? What spongiform quartz? and stalactic quartz? Does quartz ever form mountain masses? In what situation is it more frequently found? What is sand? What are the white pebbles in gravel? Of what is feldspar composed? What are the properties of feldspar?

It is sometimes crystallized, and almost always crystalline; and the brilliant surfaces when it is broken, are in the directions of the faces of the figure in the margin, the faces P and M being perpendicular to each other, the others oblique.



Feldspar is sometimes compact, and sometimes forms mountain masses, but more frequently it forms a constituent part of other rocks, as granite, sienite, &c. Feldspar is used in the manufacture of porcelain or china ware as it is called.

Mica.

Mica is composed of the same substances essentially as Feldspar, but in different proportions. Mica, or isinglass as it is sometimes called, is found imbedded in rocks either in small scales, or sometimes in masses of some magnitude. It very easily splits into thin layers or leaves, which are transparent, flexible and elastic. Mica is sometimes called Muscovy glass, because in Russia it is often used instead of glass for windows. It occurs of all shades from white to black. The surface of the plates of mica has a strong shining lustre; and it in fact derives its name from the Latin, micans, signifying glittering. It melts without difficulty. It is found in greater or less quantity in a large proportion of the rocks. Its elasticity, and the strength of its thin plates, renders it superior to glass for many uses. It can be scratched by a knife, but is scarcely hard enough to scratch glass.

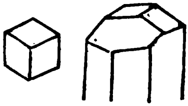
Hornblende.

Hornblende is composed of silex, alumina, lime, mag-

Is feldspar always crystalline? Does it ever form mountains, and where is it more commonly found, and in what rocks? For what is feldspar employed? Of what is mica composed? What is a common name for mica, and where is it found? What are the properties of mica? For what is mica sometimes used, and why? Is mica found in many of the rocks? Of what is hornblende composed?

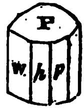
nesia, and oxide of iron. It is generally of a dark green color, and between that and black. It is heavier than quartz or feldspar, but not so hard, and is much more difficultly broken. It derives a part of its name from its being tough, and difficult to break, like horn. It can be scratched with a knife, and its powder is of a light green color. When breathed upon it gives an odor like that of moist clay, which is called the argillaceous odor.

It melts easily, and boils up or intumesces when melted. It often occurs crystallized, as seen in the margin, but is far more common in rude, shapeless masses. If however these masses be examined closely, minute crystals, having the first of these forms, may be observed. Hornblende is sometimes in granular masses, or else composed of long needle-shaped, or acicular crystals, and sometimes these long crystals diverge from a centre, and are stellar or star-shaped, or radiated like the spokes of a wheel, and the lustre is either shining, or silky. Common hornblende sometimes forms entire mountains by itself, but it is more frequently aggregated with other minerals to form rocks, as sienite, greenstone, &c.



AUGITE.

Augite is composed principally of silica, lime and magnesia. It is generally black or green, but sometimes light colored. It often resembles hornblende, but it is much harder, and will strike fire with steel; and it does not melt so easily. It is often crystallized in 4 or 8 sided prisms. Augite is found abundantly in rocks of volcanic origin, and in some of the rocks called trap-



What are its properties? From what does it derive its name? Does it occur crystallized? Under what other forms does it occur? Does hornblende ever form extensive masses? In what rocks is it contained as a part of the rock? Of what is augite composed? What are its properties? Does it ever occur crystallized? In what rocks is it found?

rocks, and which are by many thought to be of volcanic origin. It is also found in primitve rocks. It occurs massive, or without any regular form; and granular, and then it is called coccolite.

CHLORITE.

Chlorite is composed principally of silica, alumina, magnesia, and oxide of iron. It is of a green color, usually a dark green, and derives its name from a Greek word signifying green. It is in general an aggregation of small green scales; is so soft that it can be scratched by the finger nail, and feels soft and smooth, or unctuous when rubbed between the fingers. It is much softer than mica, and the latter does not feel greasy or soapy between the fingers.

TALC.

Talc is composed principally of silex and magnesia. It has many of the properties of chlorite, but it has various colors, and is rarely of a dark green like chlorite. It feels more unctuous and soapy between the fingers than chlorite. Talc is distinguished from mica, by its plates being flexible, *but not elastic like mica*. Talc is generally softer than chlorite, and is easily scratched with the finger nail. It does not easily melt, but chlorite does. Both talc and chlorite enter into the composition of rocks, and the rocks are said to be talcous or chloritic.

GYPSUM.

Gypsum is composed of sulphuric acid or oil of vitriol, united with lime. The common gypsum also contains

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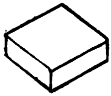
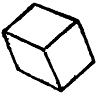
When it is granular, what is it called? Of what is chlorite composed? What are its characters? How is it distinguished from mica? Of what is talc composed? How does it differ from chlorite? How do talc and chlorite feel between the fingers? Which is most unctuous? How is talc distinguished from mica? Of what is gypsum composed?

water united to the above mentioned substances. Gypsu is generally white, but sometimes gray, red, and of var ous colors. It is often compact, but sometimes granul and crystallized. When crystallized, i is frequently in transparent plates, havin 4 sides, and can be separated into thin plate like mica and talc. If heated, it does no melt easily, but loses about one-fifth of it weight, and if transparent, it becomes white and opake.* It is used for a great variety of purposes, the most important of which, are, for a manure, for cements, and fo castings. It sometimes forms hills, but more often i forms layers or beds in other rocks, and is generally connected with salt springs or rock salt.



LIMESTONE.

Limestone is composed of carbonic acid united or combined with lime, and is called carbonate of lime; gypsum is called sulphate of lime. Limestone or carbonat of lime varies more in its appearance than any othe mineral. It occurs of all colors, and varies from a coars grained, to the most compact marbles; from a rough unseemly stone, to a fine earthy powder; and not unfrequently it is found in th most beautiful crystals. The crystals occu under more than seven hundred different form but by splitting them, the same form, or primi



What does gypsum contain besides sulphuric aci and lime? What are the properties of gypsum? Whe gypsum is heated, what are the effects? For what i gypsum used? With what is gypsum generally connected? Of what is limestone composed? By wha other names are limestone and gypsum called? Doe limestone vary much in its appearance? What ar some of the various appearances and textures it presents? Does carbonate of lime occur crystallized? Ha it many crystalline forms? Can they all be reduce to one?

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*A body is opake when the light cannot be seen through it.

tive form, is obtained from all of them. The primitive form is a rhomboid, a solid, having all its faces equal to each other, but the angles not right angles.

The crystallized transparent carbonate of lime is called calcareous spar, and has some remarkable qualities. If a rhombic crystal of calcareous spar be placed on a piece of paper, with a fine line of ink drawn upon it that may be distinctly seen through the crystal, the line appears double, or there appears to be two lines near together; if now the crystal be turned around gradually, the lines approach each other until only one is visible, and by turning it still farther they again appear, and recede from each other until you have turned it half round, after which they again approach until only one line appears. This is called double refraction.* Calcareous spar becomes electrified† by rubbing it, and even by pressing it between the fingers, and retains its electricity for some time.

Notwithstanding the great variety of appearances presented by carbonate of lime, it may be easily recognized by the following characters. Carbonate of lime can be scratched with a knife; acids when poured on it boil up or effervesce violently; and when heated highly, it becomes quicklime, in which state it is easily recognized by the taste, and by its burning the tongue; and if a large fragment of it have water thrown upon it, it becomes hot and crumbles to a white powder.

What is the primitive form? What remarkable properties are observed in calcareous spar? How may carbonate of lime be recognized?

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* Light is said to be refracted when, in passing through a transparent body, it is bent out of its course. A stick, when put into water, appears bent, and to have a different direction in the water from what it has out. This is owing to refraction.

† Electrified bodies attract light substances; and if the electrified surface be of any considerable magnitude, on approaching it to any part of the body, a small spark is seen, and a snapping noise heard. The spark is similar to lightning, and the noise to thunder, only infinitely smaller.

Limestone occurs abundantly in every country;
forms mountains, and even ranges of mountains. T
strong granular and compact limestones are used as ma
bles; many of them make good building stones, a
lime; chalk is used for marking, and making lime a
whiting, and marl is used as a manure.

SERPENTINE.

Serpentine is composed of silica, magnesia, and wate
but sometimes contains a small proportion of other sul
stances, as alumina, oxide of iron, &c. Its color is gen
rally some tint of green, but often variegated. Serpen
tine derives its name from the colors being variegate
somewhat like the skin of a serpent. It is generally com
pact; rarely granular or crystalline; yields to the knif
is somewhat unctuous to the touch, and is capable of r
ceiving a high polish. It is sometimes used as a marbl
and limestone sometimes contains serpentine disseminate
through it in grains, and is then called *verd antiq*
marble. Serpentine forms considerable masses in man
parts of the world, and it seems to be the repository of th
chrome iron, used so extensively to obtain chromate
lead or chrome yellow.

SLATE AND CLAY.

These substances are mostly composed of silex and a
umina, and sometimes a little carbon or oxide of iro
Most of the slates can be scratched easily by the knif
and the clays by the finger nail. The slates generall
split out into thin layers, and some of the clays do th

Does limestone occur abundantly? For what are th
various kinds of carbonate of lime employed? Of wh
is serpentine composed? What is its color? What ar
its properties? For what is it employed? What
verd antique marble? Does serpentine form larg
masses? What mineral is found in serpentine, an
for what is it employed? Of what are slates and cla
composed? What are their characters?

same. When broken, they both shew a fine grained fracture, and the clay, particularly, shews what is called the earthy fracture. Both slates and clays give the argillaceous odor when breathed upon.

Slate is used for drawing slates and for pencils, for roofing buildings, &c., and the clays are employed for making bricks, and various kinds of pottery.

Slate often forms extensive masses, and clay generally occurs in detached beds, often of considerable extent.

CHAP. IV.

STRATIFICATION.

Knowing the elementary and mineral bodies of which the globe is composed, we find, by observation, that the aggregated masses of these substances, or rocks, are arranged in a regular order of superposition with regard to each other. For instance, rocks, containing coal, in one country, lie below those containing salt. In other countries, the same rocks may be expected to occur in the same relative positions. This is a fact of much practical utility; and by it, in connection with some others, a man is enabled to say whether any particular rock or mineral may probably be found in any district of country, by knowing the rocks exposed there to observation. We frequently see but one kind of rock in a distance of several miles, but more frequently there are two or more. Few rocks have their layers, or strata, in a horizontal position,

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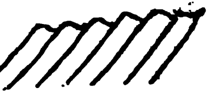
For what is slate used? For what are clays employed? Is there any regular order of arrangement of the rocks over each other? What is the position of coal, compared with that of rocks containing salt? Do rocks have the same relative positions in all countries? What is the utility of a knowledge of this? Are rocks generally in a horizontal position?

but they generally slope, or dip downwards, and sometimes they stand vertically upon their edges. This inclination or dip of the rocks, is of great importance, as rocks are thus brought to our view that would otherwise be buried deep in the earth. The strata of different rocks, when they incline, emerge in succession upon the surface of the earth, thus, so that in traveling in the direction of the dip of the rocks, you may, in a few hours, pass over many different kinds of rock. The line of dip is the direction towards which the rock slopes. The line of bearing is the direction along which the rock emerges, or more strictly, it is the line of intersection of the plane of the stratum with the horizontal plane. "In travelling over an extent of country, the direction of the strata is characterized by sameness and uniformity. There is little variety in the productions of the land, or the condition and employment of the inhabitants. On the contrary, in traveling along the line of dip, our eyes are continually regaled with a change of scenery. Every hill has a character of its own: a steep ascent on one side is met by a gentle declivity on the other. A poor soil is succeeded by one of remarkable fertility."—*Greenough's Geology.*



A knowledge of the principles and phenomena of stratification is of much practical importance, not only to the geologist, but the community generally; and may lead to the discovery of many useful rocks and minerals. It is not generally necessary to bore through rocks to ascertain what lie below them. There is a regular order in which the rocks lie over each other: knowing this arrangement,

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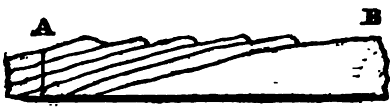
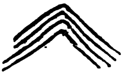
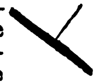
In what position are they observed? Of what importance is this inclination of rocks? In traveling across the strata what is observed? What is the line of dip? What is the line of bearing? Of what use is a knowledge of stratification? Is it necessary to bore, to ascertain the rocks below or above any particular one? How would you ascertain their positions?



and the direction in which the rocks dip, we know that they must emerge in succession. Instead of digging or boring thro' the strata at A, they may be examined by traveling towards B, in a direction opposite to the direction of the dip. The bottoms and sides of water courses, and the cliffs in the hills and mountains, are the situations where the rocks can be examined to the greatest advantage. In this way, as the different strata emerge in succession, they can be examined with any required degree of attention, and better than by boring, as then but a very small portion of the rock can be exposed to observation. If the line of dip be known, the line of bearing is also known, for it is at right angles to it. If the line of bearing be known, the direction of the dip does not follow, for it may dip in two directions from that line, thus, as the sides of a roof from the ridge. When rocks dip, their inclination is expressed in degrees of the quadrant.* Whatever the angle or degree of inclination may be, the thickness of the stratum is measured by a line perpendicular to the plane of the stratum, (as seen in the margin.) When the edges of the strata project from, or shew themselves on the surface of the earth, they are said to *crop out*, and the projection is termed the *out crop* of the strata. . Strata generally lie upon each other like





How would you ascertain their positions? What situations are most favorable for examination? If the line of dip be known, is the position of the line of bearing known? and the reverse? How is the thickness of a stratum measured? What is the outcrop of strata? What are conformable, and unconformable strata?

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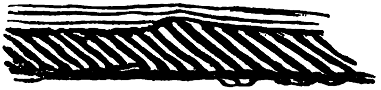
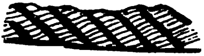
* The quadrant is one quarter of a circle. A circle is divided into 360 degrees, and of course, the quadrant contains 90 degrees, or equal parts.

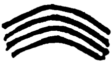
the leaves of a book, and then they are said to be *conformable strata.* Sometimes other sets of strata lie upon the last, which are conformable among themselves, but not to the first, thus, and they are then said to be unconformable.



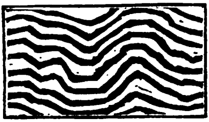
It is necessary to distinguish strata, from the thin slaty layers into which some rocks divide. When rocks are divided into regular layers of considerable extent, they are said to be stratified. The planes of stratification, and those in which the rocks most readily split, are not always the same; and this is remarkably the case in slate. The strata and thin layers into which this rock splits, are arranged thus, the coarse lines representing the strata seams, and the fine ones the thin layers of slate. Strata vary from a few inches to several feet in thickness.



Strata are not always plane surfaces, but are often curved, or bent, thus.



Sometimes the layers are much bent in various directions, (as seen in the margin,) and the rocks are then said to be *contorted.*[*]



Unless care be taken to ascertain the direction of the dip, the apparent dip is very apt to be mistaken for the real one. If the edges of the

What is the distinction between layers and strata? Do the layers of slate correspond with the strata? Are strata always in plane layers? What are contorted strata?

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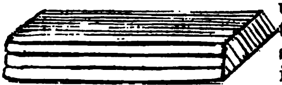
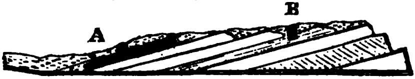
[*] M. Ramond, in speaking of the compact and argillaceous limestones and slates of Estaube, and the sandy limestone, breccias, and grits of Mont Pendu, says: "They seem to have been driven against one another by opposite forces, which, at the point of contact, have shivered them into short, irregular, tortuous veins, the entanglement of which forms the intervening masses. Figure *to yourself,*" says he, "a number of viscid liquors, differently

rock be examined in the direction of the line of bearing, the strata appear to be horizontal, when by examination in other directions, they would be found considerably inclined. The following figure will perhaps serve to illustrate. The end of the figure represents the inclination, and the top and long side shew the strata edges in the direction of the line of bearing. There is another error that may be committed by a person not attending closely to the dip and direction of the strata. "Suppose a hill to be covered with vegetable soil, and a quarry or pit, was made in it near the bottom, as at A, the stone was discovered to be sandstone; suppose another pit had been sunk near the summit, at B, which cut into limestone. It might be supposed that the limestone lay over the sandstone stratum, when it is in reality below it." In this particular instance two strata intervene in the figure.





In limestone mountains, the fissures are apt to be mistaken for strata seams. These partings and seams are

Is there any liability to mistake the direction or quantity of dip? Is there any liability to mistake the positions of rocks on hills? What causes the difficulty of ascertaining the stratification of limestone in some cases?

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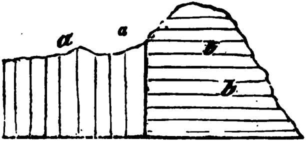
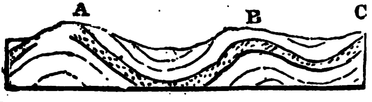
colored, spreading themselves in whirling laminar in the vessel in which they are poured,—watch a thick column of smoke floating in the air,—you will have before you an image of the confusion which prevails in these rocks. The struggle of two conflicting masses,—the repeated assaults of the one, the persevering resistance of the other, this is the idea naturally suggested on contemplating the contorted veins in these rocks. 'Tis a sea consolidated in a storm, the violence of which may still be seen in the petrified waves."—*Greenough's Geology.*

sometimes nearly vertical, when the strata are horizo
These sometimes enlarge so as to be more conspic
than the strata seams. " To add to the difficulty it
frequently happens, that a calcareous deposition, li
coat of plaster, covers the face of a rock; this has
formed by water running over the surface and depos
calcareous particles upon it. This deposition somet
conceals the stratification seams, as completely as a
of plaster covers the rows of brick in a building.
vertical seams or partings, are sometimes open, and s
times have formed parallel ridges which efface th
pearance of the strata seams in one part of the rock
not in the other; and in such instances, we have a
rently a mountain mass, in which the strata are p
horizontal and partly vertical."—*Bakewell's Geolog*



In the accompan
figure, *a*, *a*, are th
parently vertical st
and *b b*, the horiz
and proper strata.

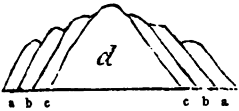
Strata generally
pear to terminat
their outcrop. When the strata are bent, the same st
may often be found again not far from their apparent
mination, as may be observed in the figure. The st



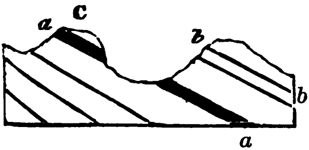
that appea
terminate
A, are foun
gain on the
er side of
the curvature or dip varying, they approach and the
cede from the surface, dipping in opposite directions a
B and C. A stratification analogous to this, is ofter
served adjacent to some of the mountain ranges, w

Do these strata ever appear vertical, when they in reality horizontal? Do strata always terminat their outcrop? Do strata rest or lean against mo tains?

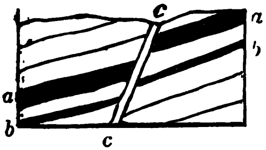
the strata appear to rest against the sides of the mountain masses; *d* being the mountain, and a a, b b, c c, similar strata of rocks.



There is another instance in which the strata may not terminate at their outcrop, but appear again in the opposite hill, as *a a*, but *b b*, by its prolongation, would pass over the hill *C*. Where the strata are nearly horizontal similar strata are almost always found on the opposite sides of a valley, as if they had been formerly continuous, and the valley since formed by some powerful cause.

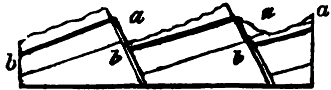


There is another point in relation to stratification, (and it is also applicable to *veins*, in rocks that are not stratified,) that, from its practical importance in mining, should be well understood. The bed of coal, or vein of ore, appears suddenly to terminate. When this occurs, the bed may be found again, either above or below its original level. At its apparent termination, a fissure, or else a different kind of rock, occurs, generally in the form of a vein, as *c c*. Repeated observation has shown, that if, at the apparent termination, the rock cutting it off inclines towards you, so as to project over your head, the bed of coal, or other mineral, lies at a lower level on the other side of *c c*, as though the mass of strata on one side of the vein had slid down to a lower level. In the figure, *a a* and *b b* repre-



Does the same stratum ever appear on the opposite sides of vallies? When beds of coal terminate suddenly, can they be regained? and how? What has been observed of the positions of the beds of coal, in reference to the sloping of the vein or dyke?

sent beds of coal cut off by the vein or dyke, *c c*. In proceeding from *a* to *a*, the reverse of the above would take place. Analogous appearances are sometimes presented upon the *surface* of the earth, where there are high precipices of rock in successive ranges of hills, as in the figure. The same strata apparently occur in each successive ridge, and the strata all dip in the direction *a b*, and the masses, forming the ranges of hills appear to have cracked off, and each succeeding mass to have slid down over the cliff of the preceding.



The various phenomena of stratification indicate, that powerful forces have been put in action, thus to bend and break up the solid strata of the globe. In some parts of the world, the stratified masses of great extent are thrown into every variety of position, and as much confusion prevails in their arrangement, as in the masses of ice that we see in our rivers, where the currents or tides have brought large fields of it crushing against others, breaking them into large fragments, thrusting and overwhelming them in every direction, and the frost cementing them thus together.

CHAP. V.

FORMATIONS.

When a series of strata of a similar rock, are arranged with occasional strata of other rocks intervening, which recur in different parts of the series, they are regarded as

What appears to have caused the present position of the beds? Is there any analogous appearance in the hills on the surface of the earth? and what is the appearance presented by such hills? What do the phenomena of stratification indicate? What is said of confused stratification? To what is it compared?

having been formed during the same epoch, and under similar circumstances; and such series are called, by geologists, *Formations*. Thus the strata of sandstone, slate, limestone, &c. accompanying coal, are altogether, called the *coal formation*.

The idea may have been derived from what precedes, that all rocks are stratified, but it is not so. Many shew no traces of stratification, but are in large, shapeless, mountain masses, as granite, sienite, porphyry, &c.

All rocks, whether stratified or not, are traversed by veins of various mineral substances. Most of the metalic ores are found in veins. Veins appear to have been once open fissures, formed by the cracking of the strata, and since filled with the substances now occupying them.

The walls of a vein are the rocks contiguous to it. The upper side of the vein, when inclined, is called the *roof*, and the lower the *floor*. In the same rock, there are frequently several systems of veins, formed at different times, and then we can tell the relative ages of each, for the oldest is intersected by all, and the newest is not crossed by any of the others. Veins vary from a few lines to many feet in breadth. They are sometimes of the same materials as the rock traversed by them, but generally different.

It has been observed, that all the rocks might be referred to two general classes, which were called the primitive and secondary rocks. Geologists have since arranged rocks into a greater number of groups. A class of rocks was observed that had some of the crystalline structure, like primitive rocks, and they also contained the re-

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What are formations? Are all rocks stratified? What are all rocks traversed by? Where are most of the ores found? What are veins? How do they appear to have been formed? What are the walls of a vein? What its roof? What its floor? Is there often more than one system of veins? How can the relative ages of the veins be determined? Are veins ever of the same material as the rock? Into what two classes can rocks be divided? What are transition rocks? What secondary?

mains of animals imbedded in their mass. From these rocks shewing characters intermediate between the primitive and secondary rocks, they were called *transition rocks*. There is another class constituting the most recent rocks, called *tertiary rocks*. More recent still, in poin of time, are the deposites of sand, clay and gravel, tha we see almost every where, and which cannot have bee placed in their present position by the action of water running as it does in the present water-courses. This i called *diluvion*, or a diluvial deposit, from its having bee deposited, apparently, during the deluge.

Most recent of all is the alluvion, or alluvial deposit which is now forming by the action of water and winds The mud and sand brought down by rivers and torrents and deposited in a different situation from what it had before, is *alluvion*. These classes of rocks and deposites arranged in the order in which they occur naturally, ar

1 ALLUVIAL deposites;
2 DILUVIAL "
3 TERTIARY rocks;
4 SECONDARY rocks;
5 TRANSITION "
6 PRIMITIVE "

Within a few years, it has been proposed to substitut other names, upon the ground that these introduce thec retical considerations, as to the time, or mode, of formatio of the rocks. If such names be substituted as may suggest the idea of *relative positions only*, observers will b less apt to be influenced by particular theories, when the come to the observation of facts. In conformity with thi plan, Conybeare and Phillips have arranged rocks in fiv classes, viz:

1 SUPERIOR;
2 SUPERMEDIAL;
3 MEDIAL;
4 SUBMEDIAL;
5 INFERIOR.

In this classification, the coal formation, in the lowe

What are tertiary rocks? What are alluvial depos its? What diluvial? What is the order in whic these classes of rocks and deposits are arranged? Fo what reason has it been proposed to substitute othe names for those just mentioned? What is Conybear and Phillips' arrangement?

part of the secondary of the other arrangement, is taken as the *medial* class, the submedial corresponding with the transition, and the inferior to the primitive rocks. The supermedial embraces the upper part of the secondary class, and the superior, the tertiary rocks and the diluvial and alluvial deposites.

De La Beche has also given a classification of rocks that is very good. He makes two general classes, like Lehman, calling them Superior and Inferior rocks; the first comprehending all the rocks containing fossils, and the latter corresponds with the primitive rocks.

The first, or superior rocks, are divided into groups, according to the arrangement of the organic remains contained in them. The inferior, are divided into stratified and unstratified rocks, and they are described in the usual manner. The arrangement which has been generally employed in describing the rocks, will be adhered to in this treatise, as more convenient, and more easily applied by those who have made no great progress in a knowledge of fossils.

The rocks will be described in the order of their position, beginning with the lowest. "If any rocks can with propriety be denominated primary, or primitive, they are those which are most widely spread over the globe, in the lowest relative situation, and which contain no remains of organic existence. Primary rocks are supposed, by geologists, to constitute the foundation on which rocks of all the other classes are laid; and if we take an enlarged view of the structure of the globe, we may admit this to be the fact,—but the admission requires certain limitations." The same causes that have produced certain rocks in masses of great extent below all the other rocks, have, in certain situations, reproduced them in smaller masses, covering the transition and secondary rocks.

What formation is assumed as the medial? To what do the inferior, submedial, supermedial and superior correspond in the former classification? What is De La Beche's arrangement? What are primitive rocks, and what are they supposed to constitute the foundation of? What is the structure of primitive rocks?

"The structure of primary rocks is crystalline; they form the central parts of the most elevated mountain chains, and they occur at the lowest depths that have been yet explored, and are hence believed to be the most ancient of the rock formations."

The *principal rocks* called *primitive*, are—

1 GRANITE; 3 MICA SLATE.
2 GNEISS, OR SLATY GRANITE;

There are some other primary rocks that occur imbedded in, and interstratified with, the principal primitive rocks. They are called *subordinate rocks*. They are—

HORNBLENDE ROCK; CRYSTALLINE LIMESTONE;
SERPENTINE " QUARTZ ROCK.

"The three principal rocks of the primary class, granite, gneiss and mica slate, might with propriety be regarded as belonging to one formation. They are composed essentially of the same minerals, varying in different proportions, and are rather modes of the same rock, than different species. They pass by gradation into each other, as one or other of their constituent minerals becomes more or less abundant; they alternate with each other in various situations, and may be regarded as cotemporaneous. It may, however, for convenience of description, be proper to treat of each separately."

GRANITE.

Granite is an aggregation of grains, or masses of *quartz*, *feldspar*, and *mica*, adhering to each other without any cement. The feldspar and mica are generally crystalline, but the quartz rarely shews this structure.

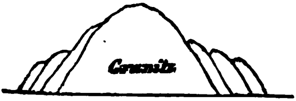
What are the principal primitive rocks? What are the subordinate primitive rocks? Do granite, gneiss and mica slate belong to one formation? Do they bear any analogy with each other? Do they alternate with each other? Of what minerals is granite composed? Are the minerals crystalline?

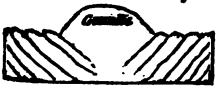
The minerals of which granite is composed are aggregated differently in different granatic rocks, and often, even in the same rock, the grains and crystals in one part of the rock are coarse, in the other fine, and perhaps one of the minerals may predominate in one part, and be in small quantities in another. When granite or any other rock is fine grained, with large crystals of feldspar imbedded, it is said to be *porphyritic.*

Feldspar, in general, constitutes by far the largest part of granite, and its colors are various, but generally white or red. The mica is variable also, in color, but is generally black or white.

Sometimes other minerals replace the mica entirely, or in part, in granite, without altering its general character. When hornblende supplies the place of mica, the rock is called sienite, and when talc, or chlorite enters into the composition, it is called talcose, or chloritic granite, and sometimes protogine.

"Granite is considered as the foundation rock on which slate and all secondary rocks are laid." When granite rises above the surface, the beds of other rocks, in the same district, rise toward, and lie against it, thus; but there are instances where they appear to pitch under the granite, as seen in the figure.





The aspect of granite mountains is extremely various. When the beds are horizontal, or when the rock is soft and disintegrating, the summits are rounded and unpicteresque. When hard and soft granite occur

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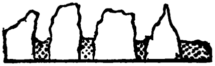
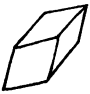
Are the minerals aggregated in different proportions in granite rocks? When are rocks porphyritic? Which mineral predominates in granite? What is sienite? and what is protogine? How do rocks lie in the vicinity of granite mountains? Do they ever pitch or dip under granite? Does the aspect of granite mountains vary? When hard and soft granite alternate in beds, what is the appearance of the mountains?



in the same mass, the soft decomposes, and le hard in large, loose masses upon the soil, or if th alternate and highly beds, the hard granite for and almost inaccessibl as seen in the figure.



Masses of granite are commonly divided by fis to large blocks, which often approa rhomboidal form, thus, and sometim lumnar structure may be observed. ite is rarely found at any great elevati United States. It is not often observ cept in beds or veins, or interstratified with other New England.

Granite often forms veins, traversing the supe bent rocks. This is a fact of some importance i logical point of view.

There is a variety of granite very finely gra almost compact, called by the English geologists feldspar; and by the French, described under t of *Eurite.*

Another variety of granite is called *graphic* In this variety, the feldspar greatly predominates, quartz is arranged in it somewhat in the form of Chinese letters, thus. This variety of granite decomposes readily, and, during its decomposition, the potassa, or soda, contained in the feldspar is by the rain, or by water percolating through it, an a clay used in the manufacture of porcelain, an kaolin and porcelain clay.

Granite supplies a durable material for arch but as some of the varieties crumble by the actio weather, care is required in its selection. In s proper building materials, observe whether the ro

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Into what shaped masses is granite often d Does granite often form veins? What is eurite is graphic granite? What clay is formed by th position of this granite? For what is granit What is necessary in selecting granite for buil natural situation, and where exposed to the weather, shews any appearance of having crumbled. If the rock is firm, and not easily crumbled, where it has been long exposed naturally, it will stand well if put into buildings.

GNEISS, AND MICA SLATE.

Gneiss and mica slate are often interstratified with each other and with granite, and are generally considered as contemporaneous, or formed at the same time.

Gneiss is composed of the same minerals as granite; viz: quartz, feldspar and mica, and is a slaty granite. Granite and gneiss pass into each other by almost insensible gradation. If in granite the feldspar be diminished in quantity, and the mica increased and arranged in layers, the granite loses its massive structure, and becomes slaty, and then we have a true gneiss. Bakewell, an English geologist, who has been a close observer of facts, thinks that the stratification of gneiss has been confounded with its slaty structure, and this structure, he thinks, is the effect of crystallization. Gneiss is employed for many purposes, among which are: for building and flagging, and some varieties are good stones for standing fire in furnaces, fireplaces, &c.

Mica slate, or micaceous schistus, as it is sometimes called, is composed essentially of quartz and mica. Feldspar is not uncommon in this rock, but is not esteemed an essential constituent. Mica slate passes by slight gradations into granite and gneiss. This rock is very fissile, or easily split in one direction; its color is generally gray, or inclining to green or yellow, and it has generally a pearly or shining lustre. Mica slate and gneiss are often bent and contorted. Crystals of garnet and of staurotide are the most common minerals imbedded in mica slate.

Are gneiss, granite and mica slate interstratified? Of what is gneiss composed? How does granite pass into gneiss? For what is gneiss employed? Of what is mica slate composed? Is it fissile? What is its appearance? Is it ever contorted? What are the minerals imbedded in it?

Mica is sometimes either entirely or in part replaced
talc or chlorite, and then the rock is called *talcose*
chloritic slate. Gneiss and mica slate are nearly simi
in their constituents, and geological positions; and m
of the metalic ores and minerals that occur in one, oc
also in the others. Crystalline limestone, hornblende a
serpentine, more frequently occur in mica slate, than
gneiss.

HORNBLENDE ROCK.

Rocks in which hornblende predominates, are not
common in beds in primitive rocks. When the rock
slaty, it is called *hornblende slate* and *gneissoid hor*
blende. Augite rocks are also not uncommon. Hornblen
and feldspar, and augite and feldspar, under certain c
cumstances, form particular rocks, which will be discu
under the term of *trap rocks*.

SERPENTINE ROCKS.

Serpentine rocks are mostly composed of serpenti
with small quantities of minerals imbedded. Most
these minerals contain magnesia as a constituent.

Serpentine rock sometimes forms mountain masses, a
is sometimes magnetic. Serpentine is frequently mix
with primitive limestone, and then forms a beautifully
riegated marble of various shades of green, yellow, bl
and white, like that near New Haven, and called v
antique marble.

CRYSTALLINE LIMESTONE.

Crystalline limestone, of which statuary marble i
variety, occurs forming immense beds in gneiss and m

When talc or chlorite replaces the mica, what is
rock called? What subordinate rocks occur most
quently in mica slate? When hornblende rock is sl
what is it called? Are augite rocks found in primi
rocks? Of what are serpentine rocks composed? W
substance do most of the minerals that occur with
pentine contain? Does serpentine ever form large m
es? When mixed with limestone, what does it form

slate. The common grave-stones of white marble, are of this limestone. A bed of this rock extends, with few interruptions, 700 miles in length; beginning in Canada, passing through Vermont, the western parts of Massachusetts and Connecticut, thence through N. York, New Jersey, &c. to Virginia, and is extensively quarried in a great many places, and supplies most of the marbles used in this country. Limestones that take a good polish, are called marbles.

QUARTZ ROCK.

This rock is composed of grains of quartz, aggregated without cement. It is usually white or stained, or shaded with gray, red and yellow. Its structure is slaty, but in its small masses, it is nearly compact. It is used as a flagging stone, and fire stone.

CHAP. V[illegible]

TRANSITION ROCKS.

Transition rocks lie immediately over the primary ones when both occur together, and are distinguished from the lower, or primitive rocks, by their containing some of the remains of plants and animals. The fossils of the transition rocks "may be regarded as the most ancient records of our globe, imprinted with the natural history of its earliest inhabitants." "Transition rocks are the principal

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In what rocks is crystalline limestone found? Does it form extensive masses? Is any instance given in his country? Of what is quartz rock composed? What is its appearance? What its structure? and what its uses? How are the transition rocks situated with relation to the primitive? How distinguished from hem? What may fossils be regarded?

repositories of metalic ores, which occur both in beds veins more abundantly in many of the rocks of this (than in primary rocks."

Geologists have often been perplexed in their atte to draw a well-marked line of distinction between pr ry and transition rocks; the difficulty has arisen ch from their arranging slate with the primary class. long as it may be proper to class rocks containing org remains, with the transition rocks, we must place sla mong them. Nor can this be invalidated by the fact, in some slate rocks, no vestiges of animal or veget remains occur; for, among the secondary strata abo ing in such remains, we often meet with alternating l in which they are never found; but we do not, on account, class them with primary rocks." The follov are the principal transition rocks, slate lying next primitive rocks:

1 TRANSITION, or mountain limestone;

2 GRAYWACKE, and graywacke slate, passing int red sandstone;

3 SLATE, and its varieties.

SLATE. Roof-slate, and the slate of which school-s are made, are well kn[illegible] varieties of this rock. sometimes called *clay sl[illegible] argillaceous slate*, and *gillaceous schistus.* Th[illegible] is a soft kind of slate oc ring with coal, and calle[illegible]*ate clay* and *shale;* this not be confounded with *clay slate.* The colors of are, gray of various shades, blue, green, purple and "Slate rocks are commonly divided into beds of va degrees of thickness, which, generally, are much el ted, and from the natural divisions of the rocks, they form peaked and serrated mountains." "Slate has described by former geologists, as distinctly stratified cause it splits easily into thin laminæ, and the dire of the laminæ is asserted to be in the direction of the l

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In what class of rocks are metallic ores abund What rock is lowest in the transition rocks? What the principal transition rocks? What are the c names for slate? What must slate not be confou with? Is slate distinctly stratified?

opposition to the authority of many eminent geolo-
[maintain that slate, unless it be of a soft or coarse
approaching to shale or to graywacke, invariably
n a transverse direction to that of the beds, making
hat direction an angle of about 60 degrees." Suc-
g observations have confirmed the above statement.
e rocks vary much in quality in the same moun-

When magnesia enters into the composition of
they are distinguished by their green color, and
ito chloritic and talcose slate. Whetstone slate, and
ire varieties of talcose slate, containing impercepti-
ticles of quartz. Roof slate is generally imbedded
arse slate. The varieties of this slate are preferred
lit into thin even layers, with a smooth, plane sur-
Slate is regarded as one of the rocks in which ores
l more than in any other.

ywacke and graywacke slate, in their most com-
rms, may be described "as a coarse slate, contain-
rticles or fragments of other rocks or minerals,
g in size from two or more inches, to the smallest
hat can be perceived by the eye. When the im-
particles become extremely minute, graywacke
into slate. When the fragments and particles are
ous, and the slate in which they are cemented can
y be perceived, graywacke becomes coarse sand-
r gritstone." When the fragments are larger, and
r in their forms, the rock forms what is called a
. When the rock contains rounded fragments and
, it is called *pudding stone.*

fragments of graywacke, including the breccias
idding stone, are always of the lower rocks, and
f the upper strata.

red sandstone, called old red sandstone, is a gray-
colored red by the oxide of iron. There is another

---

n magnesia enters into the composition of slate,
it distinguished? What are whetstone, slate and
What varieties of slate are preferred for roof
Is slate a metalliferous rock? Describe gray-
When does it become gritstone? When breccia?
pudding stone? What is old red sand stone?

red sandstone, called new red sandstone, occupying a higher situation in the geological series, and it is times difficult to distinguish them. The red san quarried so largely for building, near Middletown, and in New Jersey, is by some thought to belong to these sandstones, and by some to the other. Red stone is a rock of considerable importance as a bu material. When beds of clay, or argillaceous be ternate with this rock, the soil is generally very f but where the sandstone alone prevails, the land is a sterile waste. A deposit of red sandstone extend few interruptions, from Vermont, through Massach and Connecticut, down Connecticut river to Middl thence to New Haven, thence to the Rappahann Virginia, a distance of seven hundred miles. Cl wood, fossil bones and impressions of plants and fish been found in it, and in the argillaceous rocks imb in it. Copper and lead ores are found in it in some as at Simsbury, Ct. Belleville, Somerville, &c. Ne sey, and Perkiomen, Pennsylvania; and these ores times contain silver and gold in small quantities.

Transition, or mountain limestone, is one of th important of the transition rocks. Its mineral char vary considerably. Its usual color is gray, but i reddish, brown, or black. It is often much varie veined, and spotted. This limestone is rarely as c line as primitive; or so compact and earthy in its t as secondary limestone. It often alternates with sla graywacke slate, and the strata are sometimes ren bly contorted. It is the mountain limestone, upon as a basis, the coal formation is generally found r

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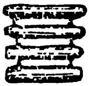
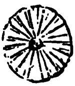
Is it ever difficult to distinguish between the ol new red sandstone? For what is red sandstone en ed? What are the agricultural characters of red stone? Where is there an extensive deposite o rock? What fossils have been found in it? Wha and where? Is transition limestone a rock of an portance? Describe it. What does it alternate Are the strata ever contorted? Upon what do coal formation generally rest?

This rock contains a great variety of organic remains, and the individual fossils are, in some places, exceedingly numerous; the rock in fact appearing to be formed of the aggregated remains of coralline animals, and of those having a shelly covering, called testaceous animals. Mountain limestone is also called metalliferous limestone, from its containing large quantities of metallic ores. The ores found in this rock are mostly lead ores, which often contain a considerable portion of silver. The lead and silver obtained in Derbyshire England, and in the Hartz mountains in Germany, are from this rock; and the mines of lead in Missouri and Illinois are in this, and the associated rocks, and in the soil produced by their decomposition. This limestone is also called *encrinal* limestone, from the great numbers of fossil encrinites imbedded in it. The encrinites are sometimes called screw-stones, from their bearing some resemblance in form to a screw, thus. They are also called, in common language, wheel-whirls, because the parts seen in the sketch separate into thin circular plates like a wheel, and generally appears thus— The heads of the encrinite are often found in the limestone, and are mentioned by people unacquainted with fossils, as petrified walnuts, petrified acorns, &c. It is almost invariably the case, that mountain limestone is found abounding in fissures and caverns. Most of the caverns in England, Germany and the United States, are in this rock. Rivers that flow in it are often suddenly engulphed, and pursue, for a considerable distance, a subterranean course. Large springs and streams burst suddenly out from the hills.





Does transition limestone contain many organic remains? and of what classes of animals? What are other names for mountain limestone? What ores are most abundant in this rock? From what does this rock derive the name encrinal limestone? What are the encrinites sometimes called? What have the heads of the encrinite been called? What does this limestone abound in? What is said of rivers and springs?

Where this rock approaches the surface of the earth, in many parts of England and of the United States, it shews a great number of deep, funnel-shaped cavities, some of them 100 or more yards across, and 100 or 200 feet deep, and some only a few yards in width and depth. In England they are called swallow holes, because they swallow up the streams of water that sometimes run into them. In the United States they go by the name of sink holes, because the earth is sometimes observed to sink and form them. There is generally a cavity in the bottom, through which the water is conveyed into the caverns and fissures underneath. They appear to have been formed by the water running in the fissures of the rock, and gradually dissolving it. This appears to have continued until the spaces became so large, that the rock was not strong enough to support the superincumbent weight, and by falling in, caused the earth above to sink, and form large cavities upon the surface. The edges of these cavities continually crumble away, until the cavity has a funnel shape, sloping steeply down on all sides to the centre. These sink holes may be observed in great numbers a few miles south of St. Louis Missouri; also in some parts of Kentucky, Tennessee, Illinois, &c. The great caverns in some of those states, communicate with numbers of these cavities, and in some places, the light may be seen through the bottom of the sink holes, by the observer, when standing in the caverns below.

Nodules of hornstone sometimes resembling flint, are seen in this limestone in many parts of the country.

Mountain or transition limestone is generally sufficiently firm to take a good polish, and from its being often beautifully variegated, it is used as a marble. It also makes good lime when burnt.

Where the rock approaches the surface, what are observed? Describe the sink or swallow holes. How do they appear to have been formed? Where may these holes be observed? Do they ever communicate with caverns? What mineral occurs imbedded in the form of nodules? Does transition limestone take a good polish? For what is it employed?

CHAP. VII.

SECONDARY ROCKS.

Geologists now divide the secondary rocks, into upper secondary, and lower secondary. The most important rock formations, in an economical point of view, are the coal formation in the lower secondary series, and the rock salt or saliferous formation in the upper secondary.

The rocks associated with coal, are called *coal measures*. The coal measures consist of a series of alternating layers of coal, slate, sandstone, and sometimes limestone, the alternations being frequent and indefinitely repeated.

The sandstones of the coal formation are quite tender and micaceous. Some of them afford good free stones for building, whet-stones, grind-stones, flagging-stones, &c. The shale, or slate clay, differs from clay-slate, in being more tender, and often containing the impressions of vegetables. An ore of iron, called clay iron stone, is almost constantly found in the shale of the coal measures, either in distinct layers, or in courses of nodules. The occurrence of this, the most useful of the metals, directly associated with the combustible and flux necessary to reduce it, is an instance of arrangement happily adapted to the purposes of human industry, and is one of the proofs that the distribution of the rude materials of the earth, was determined with a view to the convenience of its inhabitants. No well marked line of distinction can be drawn, in the *appearance* of the rocks between the lower secondary and transition, but there is a remarkable difference in the na-

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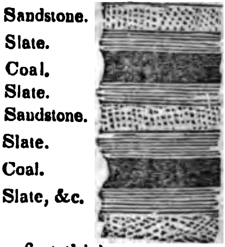
What two great divisions are made of the secondary rocks? What are the most important rock formations in these divisions? What are the coal measures? For what are some of the sandstones of the coal measures used? How does shale, or slate clay, differ from clay slate? What ore of iron occurs in the coal measures? What difference is there in the fossils of the lower secondary, and the transition rocks?

ture of the fossil remains, that serves as a distinction. In the transition, it was remarked that the fossils were mostly the remains of *animals*, either coralline or testaceous. In the lower secondary, the remains of *plants* are most numerous, and they are analagous to those growing in tropical climates.

Coal occurs in regular strata, which vary in thickness from a few inches to several feet or even yards. In the same coal formation, many strata of coal occur under each other, separated by strata of shale, sandstone, &c. The series of strata which occur together, is called a coal field. "Coal fields are of limited extent, and the strata often dip to a common centre, being often arranged in basin shaped cavities, which appear to have been originally detached lakes that were gradually filled by repeated depositions of carbonaceous and mineral matter." The different strata over and under the beds of coal are frequently similar, and the same series of strata is repeated for each successive stratum of coal, thus.



Sometimes the strata between the succeeding beds of coal, are, in the aggregate, of several hundred feet in thickness, but often, they are not many feet thick, and sometimes only a few inches. In the latter case, the adjacent beds are considered as one, and wrought as one bed. The stratum over the bed of coal is called the roof, and that under it, the floor. Sometimes there are as many as forty distinct beds of coal below each other in the same coal field, but in general, only a few are of sufficient thickness, or of a proper quality, to afford profit in working. The facility of getting coal depends very much upon the strength of the roof, and the impermeability of the rock to water. At Newcastle, in England, coal is wrought at

Do many strata of coal occur in the same coal field, and how are they arranged? Upon what does the facility of working coal depend?

the depth of fifteen hundred feet, and has been found there by boring, at the depth of three thousand feet.

There has been some disagreement as to the *origin* of coal, upon the ground that if we admit its *vegetable origin*, we are bound by similar reasoning to admit that the limestones containing organic remains are *animal deposites*, arising from the successive growth and death of myriads of animated beings, and few are willing to admit that the enormous masses of rock, often some hundreds of miles in length and breadth, and many hundreds of feet in thickness, can have arisen from such a source, notwithstanding the evidence afforded by their numerous remains. Such need only glance at the effects of the combined labors of successive races of millions of millions of polypi, in the formation of the extensive reefs of coral, which obstruct the navigation of many parts of the Pacific and Indian oceans.

The abundance of vegetable remains usually found in connection with coal, and the vegetable structure that the coal itself sometimes exhibits, will hardly allow a doubt as to its origin. At most coal mines even the *thinnest layers of slate*, when split off, shew the impressions of the leaves and flat stems of the various grasses, reeds and ferns, in all their most delicate parts. The impressions between the layers of slate often give as perfect a representation of the plant, as if the plant had been pressed and dried in a book, and the leaves then opened to display it.

"Whatever may have been the origin of coal, we cannot hesitate in admitting that vegetable life on a great scale, attended the formation of coal, and both preceded, accompanied, and followed, that event; and that the causes which established its existence, were repeated many times," at considerable intervals of time, and continued to operate during the deposition of the successive strata: that a sedimentary rock in a loose and impressible form, (the shale,) was deposited with the vegetables, and enveloped, covered, and preserved them; that a fragmentary rock succeeded, composed of pebbles, rounded or angular,

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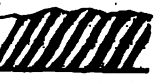
What is supposed to be the origin of coal?

or of sand cemented firmly, which were the ruins of pre-existing formations.—Silliman's Journal, xviii. p 321.

Coal and the accompanying strata usually lie parallel to each other, like the leaves of a book, and incline under a small angle to the horizon, so that the strata would emerge on the surface, thus. It is rare that the coal, or shale, crop out on the *surface*, because a diluvial or alluvial covering usually conceals the outcrop, except in the sides of ravines, the banks of streams, or the faces of cliffs. "The rock strata, are in geology, what the bones are in anatomy, when the covering is once removed, the absolute structure is at once seen."



In searching for coal, observe the kinds of rock, loose stones, and pebbles, examine the springs and beds of streams for sooty matter, and trace it as near as possible to whence it issued; ascertain the direction of the dip, then bore in a proper situation, and ascertain the quality and thickness of the bed, and whether there be more than one bed.

Coal exists very abundantly in the United States, and it is in general very conveniently situated for working to advantage. The coal mines of Virginia and Pennsylvania are more extensively wrought than any others in the U. States, and the quantity seems perfectly inexhaustible.

In Europe, where the people are mostly dependent upon the produce of their coal mines for fuel, the coal mines are extensively wrought, and under circumstances that require all the aid that the sciences yield. There are more hazards to encounter, and difficulties to overcome, in working coal mines than any other.

The coal formation which has been described, is the great or independent coal formation, and is supposed to be

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Do the coal strata generally crop out on the surface? In searching for coal, how would you proceed? Is coal abundant in the U. States? and where are the mines wrought most extensively? Are there many difficulties in working coal mines? What coal formation is that which has been described, and what are the names of the coal?

the principal repository of carbonaceous matter applicable to use. This coal is the bituminous coal, called also sea-coal, black-coal, caking-coal, &c. It gives much smoke when burning. It has generally been thought that the *anthracite coal*, of Pennsylvania, belonged to the transition rocks; but Prof. Eaton thinks he has traced its connection with the Tioga bituminous coal, and the organic remains are many of them similar to those of the great coal formation. It would seem, then, that the anthracite of Pennsylvania belongs to the great coal formation.

There is another species of coal, occurring in a different geological position from either of the others, and is called wood coal and lignite, from its shewing distinctly that it has been formed from wood. It is often found in the form of trees, branches and fruits, and still retaining the appearance of the wood, except the color. "Wood coal is found in low situations, and appears to have been formed of heaps of trees, buried by inundations under beds of clay, sand or gravel." "In wood coal we may almost seize nature in the act of making coal, before the process is completed. These formations of coal are of far more recent date than that of common coal, though their origin must be referred to a former condition of the globe, when the vegetable productions of tropical climates flourished in northern latitudes."

Jet, which is used as an ornament, is a variety of lignite which has lost its ligneous structure. Amber is generally found with lignite, and appears to have been a resinous substance that exuded from the wood, and has become changed by being so long imbedded in the earth. Amber often contains *insects* imbedded, which shews that it must

Does the anthracite of Pennsylvania seem to have the same geological position as the great coal formation? Is there any other kind of coal, and having a different geological position? What is it called? and from what circumstance? Which coal is of most recent origin? What kind of plants flourished when this coal was deposited? What is jet? In what situation is amber found? What appears to have been its origin? What does amber often contain?

have been in a soft state, and on the earth's surface, and in which they became entangled, as they do now in the gums and resins that exude from certain trees. They may be often observed in gum copal beautifully preserved.

Lignite occurs in large quantities in New Jersey, along Raritan Bay, in the cliffs, and in various other parts of the country. The large bodies of the plants are generally flattened, (as seen in the margin,) as though the weight of the superincumbent earth had pressed the sides together.

CHAP. VIII.

UPPER SECONDARY ROCKS.

The upper secondary rocks comprise all the different formations above the great coal formation, to the upper limit of the chalk series. These rocks are divided into 3 formations, viz :

1 Chalk, or cretaceous rocks, including the ferruginous and green sand ;
2 Oolitic rocks, lias limestone and lias clay ;
3 Red sandstone, including magnesium limestone.

The red sandstone goes also by the names of variegated sandstone, new red sandstone, and red marl ; and is most important as being the principal repository of rock salt. The magnesian limestone is the lowest part of this rock formation. This limestone dissolves more slowly than

What does this shew? In what may insects be observed beautifully preserved? Does lignite occur in the U. States? How do the bodies of the large plants appear? What seems to have caused this flattening?

What are the limits of the upper secondary rocks? Into what formations are they divided? For what is the red sandstone most important? What are the characters of magnesian limestone?

er limestone, and is generally of a buff color, and sandy
its texture. Some of these limestones form an excellent
ilding material, and yield a fetid smell when hammer-
. They make a *good lime* for cements, but it will not
swer for liming land, as it injures the fertility of the
l. Magnesium is found to be uniformly injurious to ve-
tation, and magnesian soils are barren. The fossils in
s limestone are not numerous.

The texture of the rocks of the red sandstone formation
very various. It appears sometimes as a reddish marl
clay, sometimes as a sandstone, and sometimes these
e interstratified, or pass into each other, and it is some-
nes associated with beds of a conglomerate rock, which
composed of pebbles and fragments of other rocks ce-
ented together.

The soil where this formation occurs is reddish, and
eep living on it have their wool tinged with red.

There is often a strong similarity between the sandstone
the coal measures, and that of this formation, but they
ay be distinguished by the latter containing gypsum.

The red sandstone formation is characterized by the
st appearance of any abundance of the remains of the
urian, or lizard-shaped animals. The remains of a num-
r of species have been found, differing in their appear-
ce from the crocodile and alligator, and some of them
ust have been from 60 to 120 feet in length. These ani-
als appear to have lived in salt water, unlike any of this
ass with which we are acquainted at the present day,
l of which belong either to the land, or to fresh water.
hey had neither feet nor fins, but paddles, like the sea-
rtle, and their tails were long, of the form of an oar, and
ted to propel them in the most agitated waters.

What are the characters of the red sandstone forma-
n? What is the color of the soil of this formation?
ow are the sandstones of this and the coal formation
stinguished? By what organic remains is the red
ndstone characterized? What appears to have been
e size of those animals? Where do they appear to
ve lived? Had they feet, or fins? Were they calcu-
ted for moving on land, or in the water?

The most valuable minerals found in the red sandsto
are, gypsum and rock salt. The gypsum is fibrous, m
sive, and crystallized. Many repositories of rock salt i
situated near the foot of mountain ranges, and althou
salt is more frequently found at a comparatively low lev
it has also been found high above the level of the sea;
in the Alps, and on the Andes.

The great salt mines of Cheshire, in England, of Wi
ictska, in Poland, and those in Germany, Spain, Ru
and Turkey, are in the red sandstone formation. T
salt of Cardona, in Spain, appears to have been an en
mous mass, in which the water has formed vallies, "lea
ing several detached mountains.—S. j. xv. p 1, 2.

"Nothing can compare with the magnificence of th
spectacle which the mountain of Cardona exhibits at su
rise. Besides the beautiful forms which it presents,
appears to rise above the river like a mountain of precio
gems, displaying the various colors produced by the r
fraction of the solar rays through a prism."—*Bakew*
pp. 187.

Hungary and Poland afford the most numerous an
extensive repositories of rock salt in Europe.

There is a formation of rock salt on each side of th
Carpathian mountains, six hundred miles in length.

"The salt mines of Welielska, near Cracow, have be
long celebrated, and frequently described: they are wo
ked at the depth of 750 feet." "At Paraid, in Trans
vania, there is a valley, the bottom and sides of which a
pure rock salt. The mine of Eperis is about 990 feet dee
Water is sometimes enclosed in blocks of salt."—*Brong
niart, Mineralogie.*

On the northern shore of Africa, not far from Algie
and Tunis, are salt lakes, communicating with the Med
terranean sea by small springs, through which, durin
the warm season, there is a continual influx of the s

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*What are the most valuable minerals found in th
red sandstone? How is rock salt situated? Does
ever form extensive masses? In what parts of Euro
is rock salt found abundantly? How is rock salt fou
in lakes in Africa?*

water, and from the deposit of salt, consequent upon the evaporation of the water, some of them have become shallow, and their bottoms covered to an unknown depth with rock salt. Some of the salt lakes of Africa dry up entirely in the summer, and leave a bed of pure rock salt. The salt springs of Africa, on the borders of Caffraria, east of the Cape of Good Hope, contain beds of rock salt variously colored. There is a remarkable formation of salt at Posa, in Castile, placed in the immense crater of an extinct volcano.

The salt of Northwich (Cheshire co. England) alternates with clay, and marl containing gypsum. The upper bed of salt is from 60 to 90 feet thick, and below this, separated by a bed of clay, is another which has been penetrated 108 feet without finding its bottom. This mine yields 156,000 tons of salt per annum. The mines and springs of salt in Europe yield 15,000,000 tons of salt per annum. Rock salt has not been found in the U. States, except far to the west of the Mississippi. "The salt mountain is situated at the head of one of the western branches of the Arkansas."—*Stoddard's Sketches*, p. 403.

Salt springs are very numerous in many parts of the United States. The water sometimes flows naturally, but more frequently it is obtained by boring through the strata where salt water is known to exist, in the vicinity of *salt licks.** These licks were the places of resort for wild animals before the settlement of the country. They were easily found when the country was newly settled, by the paths which converged from various directions to the licks, where the animals repaired to lick the clay impregnated with salt. Some of these licks are remarkable

Has rock salt been found in the U. States? Are salt springs numerous in the U. States? How is the salt water more frequently obtained than from the natural springs upon the surface? What are salt licks? For what are some of these remarkable?

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* It is necessary to drill, or bore through rocks, often several hundred feet, before the salt water is reached, and then the water rises, and *overflows at the surface.*

for the quantities of fossil bones found adjacent to them. The bones of the Mastodon, the Elephant, &c., are most abundant, and the lick called Big Bone Lick, in Kentucky, is the one at which these remains have been found in the greatest abundance.

The Mastodon was the largest land animal that is known to have existed. This animal, which is not in existence at present, was formed much like the elephant, except in the teeth; but the elephant must have seemed a pigmy by his side. The teeth of the great mastodon often weigh from six to seven pounds each, and one of the tusks is as much as a strong man can lift.

As to the origin of salt deposits, and salt springs, many opinions have been advanced. Rock salt is usually of a crystalline texture, and is associated with materials that have evidently been subjected to the action of water, as clays and sands, and conglomerates of sand, gravel, pebbles, &c., and these often contain shells, and the teeth and bones of marine animals.

All agree, that the salt deposits bear conclusive evidence of having been deposited from water.

Salt springs, in Europe, are most abundant where rock salt abounds, and from flowing over its beds, the water is doubtless impregnated. This explanation will not hold for our salt springs, for, rock salt, although it has been diligently sought for in the vicinity of salt springs in this country, has not been found.

Prof. Eaton has published a fact that goes far to prove its origin. He mentions, that fragments of the hydraulic limestone, found a few miles west of the Onondaga salt springs, when examined externally, or pulverized, presents nothing to the senses resembling common salt; but

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Which of these licks has the greatest number of those fossil bones? Of what animals are the remains most common? What is said of this animal? Upon what are all agreed in the deposition of rock salt? Will the same explanation hold for our salt springs, as for those of Europe? From what is it probable that the salt of our salt springs is derived?

when kept a few days in a moist cellar, they became incrusted with common salt.—Sj. vi. p. 242.

He has also found in some of the rocks, cubic cavities, and cavities like the hopper-shaped crystals of common salt. Although several minerals crystallize in the cubic form, none but salt are known to have the hopper-shaped form.

These facts constitute a train of evidence, which renders it probable, that the salt of the salt springs, is derived either from salt, or its elements, contained in the rocks overlying that, on which, as a floor, all the salt springs are found.

It is a fact worthy of remark, that salt, a mineral so necessary to supply the wants of man, is found abundantly in almost every country, either in its solid state, or dissolved in the water of springs. Denmark, Sweden and the eastern part of the United States, are exceptions, but they are placed in such a situation that they can easily draw their supplies from the great reservoir of this mineral, the ocean.

LIAS.

The *lias* limestone and clay, when fully developed, form a mass of several hundred feet in thickness, lying upon the red sandstone formation.

The limestone is of a bluish or light buff color, and very compact. It often contains bitumen, alumina, and oxide of iron. The finer kinds of lias limestones receive a polish, and are used for lithography. This limestone is also employed for making hydraulic cement.

The lias clay often occurs in the form of a soft clay or shale, impregnated with pyrites and bitumen. When made red hot, if more be piled on the first, it also ignites,

Is salt found abundantly in every country? Whence do people draw their supplies of salt, when they have neither rock salt or salt springs? Upon what does the lias lie? What are the characters of the lias limestone? For what is it employed? How does the lias clay appear? Can it be made to burn?

and continues to burn gradually for some time. In this way, immense heaps of this material, called alum-slate, are roasted, and prepared for making alum.*

The beds of lias clay and limestone are particularly distinguished by the number and variety of organic remains which they contain. The most remarkable of these are the bones of certain fish and lizard-shaped animals. An idea of the magnitude of these animals may be formed when it is said that places in the scull for the eyes of the animal are from 9 to 10 inches in diameter.

OOLITE.

The oolitic rocks are composed of various strata of limestone, clay, sand and sandstone. Oolite derives its name from the small globules that are imbedded in the rock, and some of the masses appear composed of little rounded globules like the roes of fish, from which it is also called roe stone. This limestone is sometimes employed as a building stone, but it is not durable. The oolitic rocks are remarkable for the great variety of organic remains contained in them. "The vertebrated animals, whose remains are found in oolite, are some of them of the same genera as those discovered in lias; but others belong to the crocodile genus, and had feet, like the living species of crocodile, and were probably amphibious:

What is made from it after it has been burnt? How is alum made? How are the beds of lias particularly distinguished? What are the most remarkable of these remains? Of what are the oolitic rocks composed? From what does oolite derive its name? For what are these rocks remarkable?

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* Alum is composed of sulphuric acid, alumina, and potassa. The sulphur of the pyrites in the clay, forms a sulphuric acid during the burning, which unites with the alumina and potassa in the clay, and forms alum. By leaching water through the burnt clay, and evaporating the water, alum is obtained. Sometimes the clay does not contain potassa, and then that is supplied by mixing common wood ashes with the burnt clay, and leaching and vaporating the water as before.

hence we may infer, that there were rivers and dry land in the vicinity."

"It may well excite surprise, that calcareous strata should so rarely be found which present distinct indications of having been formed exclusively by coralline polypi, particularly as coral rocks and reefs of great extent are so rapidly forming in our present seas. There are, however, among the strata of oolite, some which are almost entirely composed of madreporites, and have received the name of coral ragg. There are other strata which abound in the remains of fossil sponges alcyonia, and with congeries of minute millepores and madrepores."—*Bakewell's Geology*, p. 201.

CHALK.

Associated with chalk,are, a reddish brown colored sand, or loose sandstone, called iron ore ; ferruginous sand, and one called green sand, from its containing particles which give it this tinge. There are some others that have not been identified in this country, viz: Weld clay and Purbeck limestone. These strata are all placed between the oolite and chalk, and they are remarkable for containing the remains of land and fresh water animals, and plants similar to those growing under the tropics; while the chalk forming a thickness of from 600 to 800 feet above them, contains only the remains of marine animals.

Mr. Mantell concludes his "Illustrations of the geology of Sussex" with the following remarks: "The gigantic Megalosaurus, and yet more gigantic Iguanodon, to whom the groves of palms and aborescent ferns would be mere beds of reeds, must have been of such prodigious magnitude, that the existing animal creation presents us with no fit objects of comparison. Imagine an animal of the lizard tribe three or four times as large as the largest cro-

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Are there any rocks formed by the coralline polypi among the oolitic strata? What are they called? Are any filled with fossil sponges? What strata are associated with the chalk, and lie under it? For what are the strata between the oolite and chalk remarkable?

codile, having jaws, with teeth equal in size to the incisors of the rhinoceros, and crested with horns;—such a creature must have been the Iguanodon! Nor were the inhabitants of the waters much less wonderful; witness the plesiosaurus, which only required wings to be a flying dragon: the fishes resembling Siluri, Balistæ, &c."

Chalk is too well known to need description, but it varies considerably in the beds where it is found, being sometimes hard enough to be used as a building stone. Flint occurs in rounded masses in chalk, and these nodules are generally arranged in regular layers.

"All the fossils in chalk are regarded as belonging to species now extinct, and several of them belong to extinct genera." Although proper chalk has not been found in this country, a chalk formation has been shewn to exist in New Jersey, by Dr. Morton. The organic remains are similar to those of Europe, and the chemical composition the same, but the minerological characters differ. The green and ferruginous sand correspond both in fossils and in minerological character; and there is a strong probability, from recent observations, that this formation is very extensive in the United States.

CHAP. IX.

TERTIARY ROCKS.

The tertiary rocks comprise all the regular beds of limestone, clay, marl, sandstone, or sand, which were deposited since chalk. They were, until within a few years, confounded with alluvial and diluvial deposits, and were

Is chalk ever hard enough for building? What mineral occurs in chalk, and how are the nodules arranged? Are the fossils of chalk like similar animals now living? Has chalk been found in this country? Is there a chalk formation in the U. States? Do the green and ferruginous sands occur in the U. States? What do the tertiary rocks comprise?

but little noticed. It is now ascertained, that the tertiary formations are widely spread over our islands and continents, and that some of them are of considerable thickness.

"The most remarkable discovery that has been made respecting the tertiary deposits, is, that many of them contain the bones of *mammiferous quadrupeds*, as perfect in their organization, as any of the existing species of land quadrupeds; but most of them belong to genera or species that are extinct. The tertiary strata are further remarkable, for presenting the frequent alternation of beds containing the remains of marine animals, with other beds, that contain the bones of land animals, or fresh water shells. It appears that the tertiary strata were chiefly formed in detached inland seas, or lakes: hence, there is a considerable diversity in the thickness, number, and quality, of the beds, in different districts or countries."

It may be well here to remark, that the remains of mammiferous animals, or those that suckle their young, are *not found below the tertiary deposits.** "During the deposition and consolidation of the upper secondary strata, the crust of the globe appears to have remained in a quiescent state, and to have experienced few violent concussions and derangements, from internal causes." We find the upper secondary and tertiary strata arranged horizontally, or nearly so, over the inclined lower secondary,

With what were they formerly confounded? What remarkable discovery has been made respecting the tertiary deposits? What is remarkable in the fossils of the alternating beds? Where do these strata seem to have been formed? Are the remains of mammiferous animals found below the tertiary strata? Do the upper secondary rocks seem to have been deranged in their positions during their deposition? Are the upper secondary and tertiary strata arranged conformably over the lower rocks?

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* There are a few exceptions to this rule, but they are in what have been termed anomalous deposits, and are by some thought to be only apparent, but not real exceptions.

transition, and primitive rocks. The faults and dykes, so common in the lower strata, and in the vicinity of which the rocks are so much bent, contorted, and deranged in position, rarely extend into the upper secondary and tertiary strata. Where these latter rocks "have experienced any considerable disturbing force, it appears to have operated at a comparatively recent period, after the deposition of the tertiary strata," for they appear to have been raised, or depressed together. The cities of London and Paris are both situated on a tertiary deposit, which rests upon chalk, and from the basin-shape, they are termed the London and Paris chalk basins.

"The country in which the capital of France is situated, is perhaps the most remarkable that has yet been observed, both from the succession of different soils of which it is formed, and from the extraordinary organic remains which it contains. Millions of marine shells, which alternate regularly with fresh water shells, compose the principal mass. Bones of land animals, of which the genera are entirely unknown, are found in certain parts; other bones, remarkable for their vast size, and of which some of similar genera exist only in distant countries, are found scattered in the upper beds. A marked character of a great irruption from the south east, is impressed on the summits, and in the direction of the hills. In one word, no country can afford more instruction, respecting the last revolutions which have terminated the formation of the present continents."

The fossil shells found in the tertiary strata, mostly belong to genera now existing in our seas; yet slight vari-

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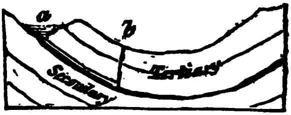
Do faults and dykes often extend into the upper secondary and tertiary strata? Where the upper secondary and tertiary rocks have been deranged in their position, at what period does this arrangement appear to have taken place? On what formation do the cities of London and Paris stand? On what do the tertiary deposits rest? For what is the country around Paris most remarkable? What shew evidences of an irruption of water? Do any of the fossil shells of the tertiary strata belong to genera now existing?

ations of form, have induced naturalists to regard them as distinct from the living species. The water from the tertiary strata is not generally pure, but often impregnated with various salts: but good water may be generally obtained by boring through these deposits, so as to allow the water to rise from the lower strata. The tertiary strata being situated in basin shaped hollows, thus, pools, ponds, or streams of water, situated at *a*, would let the water penetrate between the strata, so that if the strata be bored at *b*, the water would rise to a level with that at *a*. If *b* should lie below the level of *a*, the water would spout up, or at least, run over, at the surface of the earth at *b*. Good water is in this way often obtained from a depth of several hundred feet, and not only from boring through the tertiary rocks, but in any of the classes of rocks. It however requires much judgment to determine whether water may be obtained in this way, in any particular locality.



The tertiary strata of the Paris chalk basin, shews not only the remains of sea animals and land quadrupeds, but also those of birds, among which may be mentioned the duck, pelican, curlew, woodcock, starling, and sea-lark. Feathers have in some instances been found, shewing distinctly their impressions, in the gypsum. Fish are not unfrequently found imbedded in these strata, but they are more common in bituminous marls, and slates of the upper secondary series. Fossil fish are found very abundantly in the slaty marl quarries of Monte Bolca, near Verona. More than one hundred different species have there been found, and of these, very few are known to exist at

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Is the water obtained from the tertiary strata pure? With what is it often impregnated? How may good water be obtained? May water be obtained from great depths by this means? Are the remains of birds ever found imbedded in rocks? Are fish found fossil? Are they most common in the upper secondary, or tertiary strata? Where have they been found abundantly?

present in the waters of our planet. Fossil fish have been found in a bituminous shale, near Middletown, Conn. and in Sunderland, Mass., in considerable numbers. Fishes appear to have been suddenly and forcibly enveloped in the substance containing them, if we may judge from the contorted posture into which they had thrown themselves, apparently with a view to escape the terrible catastrophe of which they are monuments.

CHAP. X.

Diluvial Deposits.

The crumbling of rocks is constantly going on from the effects of the weather: all bare and lofty cliffs and mountains are gradually wearing down, and the process continues, "until they are covered with soil and vegetation, which protect them from further decay."

"Besides the causes which at present operate to reduce the most exposed and prominent parts of the earth's surface, and transport their materials into plains, or to the sea-shore, there are evident indications of the destructive effects of ancient inundations, which have swept over the surface of the present continents, excavated new vallies, torn off the summits of the loftiest mountains and spread their ruins in immense fragments over distant regions.

"The sand, soil, or fragments, brought down by rivers, and spread along their banks, or at their mouths, are called *alluvial depositions*. The blocks of rock, and the beds of gravel spread or scattered on the surface of the ground, composed of stone, or fragments foreign to the district in

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Have they been found in the United States? Do they seem to have been destroyed suddenly? Is there any thing to indicate that a deluge has swept over the land? What are evidences of this? What are alluvial depositions? What are diluvial deposits?

which they are spread, and which frequently cover the bones of unknown species of quadrupeds, are called *diluvial depositions*, viz: depositions which have been formed by a deluge."—*Bakewell's Geology.*

The phenomena of the diluvial ruins are highly important, inasmuch as they demonstrate the nature of the causes that have modified the present surface of our planet, and by the quantity of these wrecks, we can form an estimate of the forces in action to produce them.

Ohio, in which the rocks are secondary limestones, sandstones, &c., is found to have boulders * of various primitive rocks, as granite, sienite, &c., scattered abundantly over some parts of its surface, and no rocks of these kinds, are known to be nearer than on the north side of the great lakes. The Alps, and many parts of Germany, Russia, &c. have their surfaces strewed with huge blocks and rounded masses of primitive rocks, which are said to have been evidently brought from Denmark, Sweden and Norway, for there, exactly the same rocks, containing the same minerals, and presenting the same appearances, occur. Similar apearances occur in every country. Sand, gravel, and pebbles, are of still more frequent occurrence, which appear to have been transported from their original situations, and deposited in new ones. Most of these materials have their angles rounded off, and appear to have been rubbed and worn by friction against each other, like the pebbles in a river, or on the sea-shore.

One remarkable circumstance in relation to these traveled fragments is, that we often find them of great magnitude, and separated from their parent bed, by the intervention of deep vallies and seas; and it seems impossible, that the force of currents, however impetuous, can have driven them up the steep sides of mountains, or through

What do the diluvial ruins demonstrate? What are boulders? What is remarkable in the situation of these rocks?

*** Boulders are the loose, rounded masses of rock that we see scattered over and in the soil, in various parts of the country. Rocks are said to be *in place*, when they are in native ledges, or strata. Boulders are rocky masses, not in place.**

the deep beds of seas. The explanation that seems more reasonable, is, that they were transported on ice bergs, before the continents were uncovered by the waters of the deluge, and deposited where they are now found, by the gradual melting of the ice after it had grounded, or even when floating. Scoresby counted 500 ice bergs in North latitude 69° and 70°, and many of them were loaded with beds of rock, earth and gravel, of great thickness. Such islands of ice have been known to drift to the Azores, from the west, and to the Cape of Good Hope, from the south.—*Phil. Magazine.*

There is no difficulty in supposing the transport of gravel, sand, or pebbles, by the action of running water, to the situations in which they are found, when we take into view the violence of the currents which must have been produced during the rise and fall of the waters of the deluge.

"In order to appreciate justly the effect of such a tremendous rush of waters, we must compare it not only with common tides, but with those more violent ones with which we are acquainted." "Between the Mata Cape and the North Cape, in the place where the great canal of the river Amazon is most confined by the islands, the tide presents a singular phenomena. During the three days nearest the full and new moons, (the times of the high tides,) the sea, instead of employing six hours to rise, attains its highest elevation in the space of one or two minutes. It may be supposed that this is not effected very quietly: a terrific noise is heard at the distance of one or two leagues, which announces the pororoca, or bore, (such is the name the Indians of the district give to this terrible tide.) As it advances, the noise increases, and presently one beholds a promontory of water, from 12 to 15 feet in heighth; then a second, then a third, and often a fourth,

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What explanation is offered of their transportation? Do ice bergs now often transport large masses of rock far from their original situation? Is there any difficulty in accounting for the transport of gravel, sand and pebbles? What is said of the pororoca of the Amazon?

which follow close on each other, and which occupy the whole breadth of the canal. This surge advances with prodigious rapidity, breaking down and shaving clean away, every thing that opposes it. Wherever it passes, the coast is laid as smooth as if it had been intentionally and carefully swept.—*Silliman's Outline, in Bakewell's Geology.*

" At the mouth of a river in Nova Scotia, a schooner of 32 tons, laden with live stock, was lying with her side to the tide, at the influx of the bore, which was then about 10 feet in perpendicular height. No sooner had this mass of water reached the vessel, than that great body was turned over like a barrel, and presently disappeared. After the tide had ebbed, the schooner was so totally absorbed in the sand, that the upper rail of the deck was alone visible."

" The tides in the Bay of Fundy are said to rise sixty feet,—to come roaring in like a mighty rushing flood,—and that people and animals upon the beach, sometimes with difficulty escape with their lives."

" On the 14th Oct. 1822, a wave, which, during a storm, broke against the pier of Ramsgate, and was dashed upwards to a height of about 14 feet, fell again upon the stone pavement of the pier head; and, by the force of its reaction, raised a 36 lb. carronade, with its carriage, over a stone ledge, and precipitated it into the sea." The efforts of 20 men would have been required to produce the same effect.

"In the great tempest of Sept. 1815, among many similar effects, which happened all along the shores of New England, a vast ridgy wave, raised by the hurricane, came suddenly, in an overwhelming deluge, upon the lower town of Providence, in Rhode Island, and by its force, entire rows of houses, and stores, and warehouses, were, in a few minutes, prostrated. Ships of 300 and 400 tons, were thrown upon the wharves, knocking down large buildings by their momentum: some were carried into the

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What is said of the effects of the tide in the Bay of Fundy? What were the effects of the wave that rushed into the town of Providence during the storm of 1815?

town, thrusting their jib booms in at the 2d and 3d stories of houses; others were lodged in the streets; and a number, and those some of the largest class, (among them the Ganges, formerly a sloop of war,) after carrying away a strong bridge, were driven through a bay, usually too shallow, even for small craft, and were thrown up high and dry, upon a beach, where the salt water has never come again."—*Silliman's Outline in Bakewell's Geol'y.*

The effects of torrents, and of lakes bursting their boundaries, are still more striking, and I beg leave to refer the reader to the American Journal of Science, vol. iv, p. 125, and xv, art. ii. xi, p. 39, for an account of such phenomena, which have occurred within a few years, and in our own country.

The evidences of the deluge are imprinted in an imperishable manner, on all parts of the earth, in the transported materials, which have been spoken of, and in the vallies scooped out of the originally continuous strata, of which mention has been made in the chapter on stratification. Supposing the highest elevation of the waters to have been 5½ miles: as they were 40 days in rising, they rose at the rate of 181 feet in the time of a common flood, or ebb tide.

If we now glance at the effects of the tides which have been mentioned in the Amazon; on the coast of Nova Scotia; of the storm of 1815, in New England; that on the Catskills, in 1819; and that on the White Mountains, in 1826, how much more powerful must have been the effects, where the water was rising continually, and acquiring additional force and velocity, during its 40 days rise of the deluge. "It is not easy to exalt the imagination to an adequate conception of the terrors of that awful catastrophe. The inconceivably violent torrents and cataracts, every where descending from the hills and mountains, and meeting a tide, rising at the rate of more than 700 feet in a day, must have been resisted and aggravated in force, wherever it encountered the land, and still more by the

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Do vallies appear to have been scooped out by the deluge? Must the waters of the deluge have risen more rapidly than our highest tides?

hills and the mountain ridges. Impelled with resistless violence—it must have swept over the surface, with a force vastly greater than any thing we now know, of the mightiest rushing waters. It evidently rolled everywhere over the various inequalities of the land, in tremendous, agitated billows; and where it was narrowed by ridges, and hills, and mountains, and thus forced through vallies and defiles, it must have presented innumerable raging torrents and cataracts, of awful height, force and magnitude, compared with which, even Niagara would be insignificant."—*Silliman's Outline.*

The bones of various animals have been found in the diluvial gravel, most of which are similar to those of animals now in existence. Some of the animals whose remains are found, appear to have become extinct since the deluge, such as the mammoth, the mastodon, &c. Caves have been found in England, France, and Germany, containing immense numbers of the bones of animals, which, in some, are imbedded under a kind of yellowish earth, like that which is supposed to have been deposited while the waters were resting upon the earth, during the deluge. Some of these caves appear to have been the dens of antediluvial carnivorous animals, and into others it appears that the animals may have retired to escape the deluge. The bones of some of the animals shew the marks of teeth, as though they had been gnawed; and the bones of the hyena, bear, wolf, fox, dog, horse, ox, and a great variety of animals are found in them. The earth, in which these bones are imbedded, is generally covered by a stony mass, since formed. In some of the caves, all

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Have any bones been found in diluvial gravel? Are they the same as those now existing? Do any animals seem to have become extinct since the deluge? Are the bones of animals found in great numbers in the caves of England, Germany and France? Are these in the loose earth of recent deposit, or in diluvial mud? What do some of these caves appear to have been? What do some of the bones shew? Is the earth in which these bones are imbedded, ever covered by a stony mass?

the earth appears to have been formed by animal decomposition.

Some human bones have been found in caves of this description in France, so situated as to induce the idea that the subjects of them were destroyed by the deluge. Similar relicts have been discovered in diluvial gravel, at the depth of about 50 feet; and remains of this kind have also been found imbedded in a rock of recent origin, and which is even now in the process of formation, enclosing every thing thrown upon it by the surf. It is a remarkable fact, that, notwithstanding the great variety of fossils observed in the rocks, the remains of man are not found fossil until we come to the diluvial deposits. Geological facts shew, that the various plants and animals were created in the same order as is mentioned in the Mosaic account, and that *man* was created last, as we find his remains only in those deposits laid down since all those great changes and convulsions, which destroyed so many millions of millions of animated beings, and formed some of the rocks of their remains.

CHAP. XI.

ALLUVIAL DEPOSITS.

It is often difficult to distinguish between the alluvial and diluvial deposits, but the distinction is in general of little consequence. All those causes which are at present in action to produce changes upon the surface of the earth,

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In some of the caves, does all the earth appear to have been formed of animal matter? Have human bones been found in caves? What idea does their situation induce? Have human remains been found in diluvial gravel? At what depth? Have the remains of man been found imbedded in rock? In what kind of rock? In what deposits only do we find the remains of the human race?

Is it always easy to distinguish between the alluvial and diluvial deposits?

such as the transport of materials by torrents, rains, streams, tides, currents in the ocean, winds and the labors of animals, as shell fish, and corals, in elevating banks and reefs in the ocean; and of vegetables, as in peat-bogs; are classed as alluvial; while all those materials which have been transported to situations where the waters, under existing causes, cannot reach them, the scooping out of some vallies, and uncapping of some mountains, are referred to diluvial agency. Torrents often remove masses of rock, of many tons weight, to considerable distances; tear up trees, and bury them under deep masses of rocks, pebbles, gravel and sand. Rains wash off the loose materials on the hills: some of this is carried into the larger streams; and these, when the waters are high, wear away the banks in some places, and deposit the materials in others. Thus there is a constant tendency to levelling the country, wear down its inequalities, and deposit the materials in the sea. The making of land, by the deposit of materials thus brought down by rivers, is well known, and illustrated by the Mississippi, Ganges, and many others. The mouths of the Mississippi are more than 100 miles from its original entrance into the Gulf of Mexico, and for many hundreds of miles above, all the land seen from its banks, with the exception of now and then a sand or clay bluff, is alluvial. The alluvial deposits projecting into the sea, and deposited by rivers, are called *deltas*, as the delta of the Nile, of the Ganges, of the Mississippi, Rhone, Po, Volga, and the Danube. The delta of the Ganges commences 220 miles in a direct line from the ocean.

What are the causes of alluvial deposits? How do you distinguish diluvial from alluvial deposits? What is the constant tendency of the rains and streams? Do rivers ever deposit their materials in the sea? Are the mouths of the Mississippi far from the original entrance of the river to the Gulf of Mexico? Are the other alluvial deposits of the Mississippi extensive? What are deltas? What deltas are remarkable? How far does the delta of the Ganges commence from the ocean?

Adria, which was once a port on the Adriatic sea, is now 20 miles inland. The waters of the Ganges, and Mississippi, are so turbid, when in flood, as to give about one quarter their volumes of sediment.

Rivers which project their deltas into the sea, have generally a tendency to raise their beds in the lower part of their course, by the partial deposit of the materials brought down. This is more particularly the case with the Po, which is prevented from overflowing the country by dykes. The bed of that river has risen so much as to be higher than the tops of the houses of Ferrara. In Holland, the same phenomena is observed, but not on so great a scale. The rivers, in fact, run in a canal on the top of a hill. Since the Mississippi has been dyked, the same effect may be perceived, but to a small extent. When sailing along the Mississippi, during high water, you appear to be above the surrounding country; the dykes appear to be only two or three feet high, but on landing, you observe that they are much higher on the land, than on the river side. The reason is, that the space between the dyke and the river, has been raised by deposits from the river, to a height equal to the difference of level between the land on the different sides of the dyke; and the bed of the stream rises in the same proportion as the banks.

The transposing power of tides and currents in the ocean, must be taken into consideration, as connected with alluvial deposits. Much of the matter brought down by rivers, is borne away by tidal currents. These currents acting on the shore, in connection with the waves, remove materials from one situation, and deposit them in another. When the materials are of a loose nature, like sand,

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How far is the ancient port of Adria from the sea? Are the waters of any rivers very turbid? What ones are particularly so? What tendency have rivers which project deltas into the sea? What river particularly illustrates this fact? Is the same effect observed in other places? Does the Mississippi shew this in any degree? Do the tides and currents of the ocean transport alluvion? Are head lands washed rapidly away by the action of the waves and currents?

clay, or soft rock, the wearing away of the head-lands, against which the currents beat, is very rapid, but if pebbles, or other hard materials be contained in the banks, the lighter or softer materials are removed, and the hard ones gradually form a slope, which protects the shore in a great degree from further action.

The action of wind in transporting materials from one situation to another, is more important than one would be led to imagine, without a knowledge of facts.

"Extensive tracts of cultivated ground are sometimes converted into sandy deserts, by the drifting of the sea-sand inland. The process by which this is effected, is taking place in many situations. During high winds, the sand is driven from the sea-shore to a certain distance, leaving an elevated ridge at the further boundary of the drift. Succeeding winds blow the sand frowards, and at the same time, bring fresh sand from the shore to supply its place. Trees, houses, and even villages, have been surrounded and covered with sand, in some parts of Ireland and England, within the last century." Instances of these encroachments may be seen on many parts of our own coast. A particular instance of a light-house, on the coast of Virginia, being partly covered, and the bank progressing into the country, with a steep front of twenty or thirty feet, burying trees and every thing else in its course, is described in the American Philosophical Transactions, and is well worth the attention of the curious reader. It is well known that a considerable portion of Egypt is buried by the sands drifted upon it, and that the Red Sea is in many places rendered quite shoal by coral reefs, and by the sand drifted into it. The sand-storms of the deserts, have often been described. During the expedition of Gen.

What serves finally to protect them from further action? Is wind ever an agent in transporting alluvial matter? What are the effects produced by the drifting of sand? How is the process effected on the sea shore? Are houses, or villages, ever buried? What is said of the light house in Virginia? What is said of Egypt, and of the Red Sea? What is said of the petrified forest?

Atkinson to the Yellow Stone River, in 1825, a forest of petrified trees was observed, standing erect, but with their smaller limbs broken off, and scattered on the sandy desert beneath them. They had probably been originally covered by sand, drifted over them either by wind or by water, and remained thus long enough to become petrified. The loose sand appears afterwards to have been drifted away by the wind, leaving them monuments of the changes of the earth's surface.

Shoals often become sensibly more shallow, by the combined effects of shell-fish, and other marine animals, living, growing, and afterwards leaving their remains, as a basis for others to live and die upon successively. Coral reefs are produced in such abundance in some parts of the Pacific and Indian oceans, as to obstruct the navigation, although the animals employed in building them are so small as to be hardly visible to the naked eye.

Peat is a substance generally classed with alluvial soils, although it is a vegetable production. Peat meadows generally exhibit a wet, spongy surface, and when capable of supporting much weight, its surface will shake and tremble for some distance around, by walking or jumping upon it. Good peat cuts easily and clear with the spade; but if it resists the spade with a degree of elasticity, it is found to be less compact when dry, and of an inferior quality. The best kinds burn with a clear flame, leaving light colored ashes; but the poorer kinds often emit a disagreeable smell, and leave a heavy, red-colored ash. "The process by which the mosses are converted into peat, is clearly seen in one of them, (the spagnum palustre.) As the lower extremity of the plant dies, the upper sends forth fresh roots, like most of the mosses, the

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What explanation is offered of this phenomenon? What is said of shoals? Are coral reefs common? How large are the animals that build these reefs? What is peat? What is the appearance of peat meadows? If you walk or jump on them, what is observed? What are the characters of good peat? How can you distinguish the good from that of inferior quality? Explain the formation of peat.

dividual thus in a manner becoming immortal, and supying a perpetual fund of decomposing vegetable matter. similar process, though less distinct, takes place in mar of the rushes and grasses, the ancient roots dying, toether with the older leaves, while an annual renovation both, perpetuates the existence of the plant. Where e living plant is still in contact with peat, the roots of e rushes and ligneous vegetables are found vacillating tween life and death, in a spongy, half decomposed ass. Lower down, the pulverized carbonaceous matter seen mixed with similar fibres, still resisting decompoion. These gradually disappear, and at length, a finepowdered substance alone is found ; the process being mpleted by the total destruction of all organized boes." "The best peat is that of which the decomposion is most complete, and the specific gravity and comctness, the greatest."—*Bakewell's Geology.*

CHAP. XII.

TRAP ROCKS.

All the REGULAR *classes of rocks* have now been conlered ; that is, all the rocks that are superposed one ave the other, in a *regular order of superposition.* It ust not, however, be inferred, that the rocks are all prent in every situation. Some of them are absent from most every locality : but where two or more of them ocir together, they are laid over each other in the order in hich they have been described. For instance, the coal rmation, wherever it is found, lies above the primitive cks, and if the transition rocks be present, it lies above

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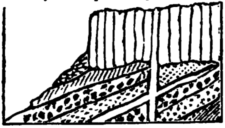
Are all the classes of rock present in every locality ? 'here any two of them occur together, how are they id upon each other ? For instance, is the coal formaon ever found below primitive rocks ?

them also. If the transition rocks be absent, the coal formation rests on the primitive rocks, as is the case with the coal near Richmond in Virginia.

Diluvial and alluvial deposits often rest on the primitive rocks, all the other classes being absent; but these deposits are never found under the transition, secondary, or tertiary rocks.

Two more classes of rocks remain to be described, which have no regular situation in connection with the other rocks, but are distributed in beds and masses indiscriminately among them. They are called *Trap* and *volcanic rocks.*

Trap rocks are mostly composed either of hornblende and feldspar, or augite and feldspar. "These rocks although they sometimes occur imbedded in the conformable rocks, more frequently cover them in an unconformable position, composing thick, unstratified beds, and often mountain masses of vast size, which have, not unfrequently, a columnar structure," and present perpendicular cliffs of several hundred feet in height.



In the sketch, columnar trap is represented as resting unconformably, on inclined strata. A dyke of the same kind of rock is shewn, cutting through the other rocks, and a bed connected with the dyke lying between, and separating them. "It is obvious that these unconformable rocks were formed and deposited at a subsequent period to that in which the lower rocks were consolidated, and their beds had acquired their present inclined positions."

Is it ever found lying upon primitive rocks? Do the alluvial and diluvial deposits ever rest directly upon the primitive rocks? Are these deposits ever found under the secondary, transition, or tertiary rocks? Of what are trap rocks mostly composed? Do these rocks rest conformably upon the others? What structure do these rocks often have? Does trap ever occur imbedded conformably in other rocks? At what period were these rocks deposited?

rm *trap* is derived from the Swedish word *trap-*
r, because these rocks often divide into regular
embling the steps of a stair. These rocks, com-
eldspar and hornblende, or of hornblende and
e called greenstone, sienitic greenstone, basalt,
, pitchstone, amygdaloid, wacke and porphyry.
tone is essentially composed of feldspar and horn-
the state of grains or small crystals, the propor-
ing, but the hornblende generally predominates.
is are sometimes so small that the different min-
iot be distinguished from each other. The rock
s name from its being frequently of a greenish
ecially when moistened. When fine grained it
exhibits a columnar structure, as in the East
rocks near New Haven, and the Palisades on
on river, and Mount Holyoke, near Northamp-
. Greenstone is sienitic when it is coarse grain-
becomes sienite when feldspar predominates.
a compact, homogenous mass of rock composed
ır and hornblende or augite. It has a greenish
sh black color, and is very tough or difficult to
t can be scratched with the point of a knife.
s easily into a black or dark green glass, and is
ly used in France, for the manufacture of glass
The iron contained in it, is, by exposure to the
further oxidized, and causes the yellowish or
red color that it usually presents on its surface.
salt is slaty, or the feldspar predominates, it be-
nkstone: when earthy in its texture and mixed
en earth, it is called wacke. When basalt or
ontain rounded cavities entirely or partly filled
r minerals, they form amygdaloid. Basalt is *ge-*

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what is the term trap derived? Describe
ne. Does it ever shew the columnar structure?
ay this be observed? Describe basalt. For
t used? What change is observed in its ap-
when long exposed to the weather? What is
e? What is amygdaloid? Is basalt column-

nerally columnar in its form, but sometimes is seen in large tabular, or in globular masses. The general aspect of the trap rocks where they form large masses, is such as at once to attract the attention of the traveler. The porphyry and basalt on the Andes, says Humboldt, "are arranged in regular columns, which strike the eye of the traveler like immense castles lifted into the sky." "Were it allowed to express a geological fact in familiar terms, it might be said that all the members of the *trap* family give indications of a firey character, and of having been troublesome neighbors to the adjacent rocks, disturbing them and even changing their nature, when they are closely associated. Besides occurring in overlying unconformable masses, all trap rocks, with porphyry, which may be placed at their head, are occasionally found intersecting other rocks like vertical walls." Walls and dykes are synonymous in some parts of England, from which these veins of trap rocks take their name. The substance of dykes is generally basalt. Dykes have been very much studied, on account of their cutting through the coal fields in various directions, and causing great derangement in the positions of the strata. This derangement has been referred to in the chapter on Stratification. Dykes vary in thickness from a few inches to several hundred feet. "The extent to which they stretch across a country has seldom been explored beyond the mining districts, where a knowledge of them is important, on account of the disturbances which they occasion in the strata." "The strata are almost always thrown down on one side of a dyke, and elevated on the other, but the dislocation is not proportioned to its breadth." "Trap dykes are generally harder than the rocks that they intersect; and when the latter are partially decomposed, often remain, forming vast walls of stone that rise above the surface of the ground." Walls of this kind extend for miles along the country in some

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What is the general aspect of the trap rocks? What is said of the porphyry and basalt of the Andes? What is the effect of trap dykes on the strata? Do basaltic dykes ever appear above the surface of the earth? Are these natural walls of any great extent?

f England. They extend into the sea, forming f rocks, and across rivers, making falls or fords. atural walls of North Carolina are basaltic dykes, of columnar or prismatic masses fitting close to each other, and lying with their lengths across the wall, and shewing their ends on its sides, as represented in the sketch.

When these walls were first observed, they were supposed to ficial constructions, from the regularity of form of arate pieces. "Dykes being impervious to water, struct its passage along the porous strata, and oc- it to rise; hence it frequently happens that numer- ings make their appearance along the course of a y which it may be detected when there is no other ion of it visible upon the surface."

effects of basaltic dykes on the different rocks h which they pass, are worthy of remark. There asaltic dyke in England that has been traced 70 and intersects various strata of rocks of different Where it is in contact with transition limestone, ter is more crystalline, a fact of geological impor- "Where it crosses the coal strata and comes in with the seams of coal, the substance of the coal ral feet is converted into soot. At a greater dis- rom the basalt, the coal is reduced to a coke or cin- hich burns without smoke, and with a clear and heat. At the distance of fifty feet from the dyke, l is found in its natural unaltered state. It is par- ly remarkable, that the roof immediately above the covered with bright crystals of sulphur. Dykes,

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e they been observed in the United States? By ppearance on the surface may dykes be recogni- hen they are not visible? What are the effects of at basaltic dyke of England, upon the transition and upon the coal through which it passes? What s are attached to the roof? What are the effects ltic dykes on chalk, shale and sandstones, when tersect them?

when they cut through chalk, convert it into a highly crystalline limestone where these rocks come in contact. Shale is changed to a flinty slate, and sandstones become of a brick red color."

It may be well to mention some experiments that have been made, which serve, in some degree, to elucidate the probable mode of formation of the trap rocks.

"All trap rocks are fusible,* and most of them form a blackish green glass after melting: hence it was inferred, that trap rocks had never been in a state of fusion, for if they had they would have been rendered vitreous.† Sir James Hall, however, reflecting on the very long period of refrigeration‡ that vast masses of melted rock would necessarily require before they were cooled to the common temperature of the earth, was induced to make experiments on lava and basalt; from which it was ascertained, that if a small portion of liquid lava were suddenly cooled, it formed a black glass, as was well known to be the case with basalt; but if the process of cooling were slow, both melted lava and basaltic became stone. When the glass which had been formed by sudden cooling was melted again, and suffered to cool very gradually, it lost its vitreous character, and was converted into a substance resembling basalt. Mr. Gregory Watt made some experiments on the fusion and refrigeration of basalt in one of his father's furnaces, which throws much additional light on the formation of the globular and columnar structure of basaltic rocks. He fused 700 lbs. of the Dudley basalt, called Rowley ragg, and kept it in the furnace several days after the fire was reduced. It melted into a dark colored glass, with less heat than was necessary to melt the same quantity of pig iron. In this glass, small globules were formed which afterwards disappeared; and as

What experiments have been made which tend to elucidate the formation of trap rocks?

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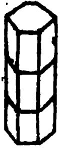
* Bodies are said to be *fusible*, when they can be melted.

† Bodies are said to be *vitreous*, when they break with a smooth surface like glass.

‡ Refrigeration means the *cooling* of a body.

the cooling proceeded the mass was changed from a vitreous to a stony substance: other globes were again formed within the stony mass, which continued to enlarge until their sides touched and pressed against each other, by which pressure the globes formed polygonal* prisms.† If part of the mass were cooled before the globular structure was destroyed, these globes were harder than the surrounding stone, and broke in concentric layers. In this manner the balls of basalt and porphyry which fall out of decomposing rocks were probably formed: they derived their superior hardness from the crystalline arrangement of the particles when in a melted state. When these globes were enlarged by a continuation of the same process, they might press upon each other and form prisms. The upper prisms, pressing by their weight upon the lower, might form concavities, or sockets, into which they would sink and remain jointed, or articulated together: such is frequently the structure of basaltic columns," thus.—



"Another experiment made by Sir Jas. Hall, on the crystallization of common limestone by heat, and its conversion into marble, tends to elucidate the effects produced by basaltic rocks on limestone and chalk, before mentioned. Dr. Hutton had advanced the opinion, that the beds of limestone were formed of the shells and exuviæ of marine animals, which had been melted by central fire, and crystallized." "It was, however, objected to this theory, that the well known action of fire on limestone rocks would expel the carbonic acid, and make them soft and pulverulent, as we see in making lime from limestone. This objection was answered, by saying, that these beds of shells, &c. were heated under the pressure of the ocean which for so long time covered the land, and that this pressure would prevent the escape of the carbonic acid, and render the limestone fusible. This was re-

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[*] A polygon is a figure having several sides: for instance, a square is a polygon of four sides.

[†] A prism is a solid body having several sides, and of equal size from one end to the other: for instance, the beams and posts of buildings are four-sided prisms. A prism may have any number of sides above three.

garded as mere hypothesis for some time, but Sir James Hall determined to try its validity by experiments." Having calculated the resistance which a column of water, 1500 feet, or any given depth, would present to the escape of the carbonic acid of the limestone, he inclosed a quantity of powdered chalk in a gunbarrel, and confined it in such a manner as to present an equal degree of resistance. He subjected the powdered chalk, thus confined, for some time to the action of a furnace; it was then drawn out and cooled, and was found converted into crystalline limestone or marble; and in one instance where the chalk inclosed a shell, the shell had acquired a crystalline texture without loosing its form. Hence, when chalk or limestone is found to have a crystalline texture in contact with trap rocks, we may, with a high degree of probability, infer that the limestone had been fused by the trap. "The constant occurrence of dykes in basaltic districts, gives a high degree of probability to the opinion, that overlying unconformable trap rocks have been erupted in a melted state like lava, and poured over the surface of the ground." Basaltic columns are frequently seen in countries that are the seat of volcanic fires, but they occur also in countries remote from any known volcanos. Organic remains are sometimes found enveloped in basalt, but this admits of an easy explanation, by supposing the basalt to have flowed like lava on the bottom of the ocean, enclosing every thing with which it came in contact. A recapitulation of all the facts bearing upon the origin of the trap rocks, would afford a mass of evidence sufficient to convince the most sceptical, of their igneous origin.

"The reason why geologists were so long opposed to the igneous origin of trap rocks, may partly be explained by attachment to received theories, and partly by the reluctance to admit a condition of our planet, so remote from present experience. It was thought an ample claim on

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What is supposed to have been the origin of the unconformable overlying trap rocks? Are basaltic columns often found in volcanic districts? Are organic remains ever enclosed in basalt? How is this fact explained?

our credulity, when we were required to believe that all the habitable parts of the globe had been for ages submerged in the ocean, without requiring the further belief, that countries now remote from active volcanos, had been repeatedly subject to the agency of subterranean fire. Yet both these positions must be granted, if we will allow a legitimate induction from established facts."

Bakewell's Geology.

CHAP. XIII.

EARTHQUAKES, VOLCANIC PHENOMENA AND VOLCANIC ROCKS.

" Accustomed to view the hills in our own country in a state of profound repose, presenting the same unvaried outline in each succeeding year, we can scarcely conceive the possibility of a whole district being covered with new mountains, and another soil, in the space of a single night: yet such changes have been produced, by the united agency of earthquakes and volcanos, within the limits of authentic history."

Earthquakes and volcanos seem to be the effects of the same cause. They frequently accompany each other, and in all instances that have been observed, the first eruption of a volcano is preceded by an earthquake of greater or less extent. Volcanos do not make their appearance in every country where the shock of an earthquake is felt; but earthquakes are more frequent in volcanic districts than in any other. Earthquakes are al-

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What conclusions must be drawn if we allow a legitimate induction from established facts. Do earthquakes and volcanos ever accompany each other? and do they depend upon the same cause? In what districts do earthquakes most frequently occur?

most always preceded by an uncommon agitation of the waters of the ocean, and of lakes. Springs send forth torrents of mud, accompanied by a disagreeable smell; or perhaps they disappear entirely. Cattle discover much alarm, and seem to be instinctively aware of approaching calamity. A deep rumbling noise like that of many carriages rolling over a rough pavement, a rushing sound like the wind, or a tremendous explosion like the discharge of artillery, immediately precede the shock, which suddenly heaves the ground upwards, or tosses from side to side with violent and successive vibrations. The ground often heaves in undulations like the waves of the ocean: large chasms and fissures are made in the ground, through which smoke and flames are seen to issue: these sometimes break out where no chasms can be perceived. More frequently, stones or torrents of water are ejected from these openings. In violent earthquakes, the chasms are so extensive, that large cities have in a moment sunk down and forever disappeared, leaving a lake of water in their place. Such was the fate of Euphemia in Calabria, in 1638, as described by Kircher, who was approaching the place, when the agitation of the ocean obliged him to land at Lopizicum. "Here, (says he,) scenes of ruin every where appeared around me; but my attention was quickly turned from remote to more contiguous danger, by a deep rumbling sound which every moment grew louder. The place where we stood shook most dreadfully: after some time, the violent paroxysm ceasing, I stood up, and turning my eyes to look for Euphemia, saw only a frightful black cloud. We waited till it had passed away, when nothing but a dismal and putrid lake was to be seen where the city once stood."

A shock rarely lasts more than a minute, but often there is a succession of shocks, with intervals of some duration.

"The extent to which earthquakes produce sensible ef-

What are earthquakes almost always preceded by? What noise is perceived before an earthquake? How is the ground affected? Are the chasms produced by earthquakes ever very extensive? How long do the shocks continue? Do they ever rapidly succeed each other?

ects on the waters and springs in distant parts of the world, is truly remarkable. During the earthquake of Lisbon, in 1755, almost all the springs and lakes in England, and every part of Europe, were violently agitated, many of them throwing up mud and sand, and emitting a fetid odor. On the morning of the earthquake, the hot springs of Toplitz in Bohemia, suddenly ceased to flow for a minute, and then burst forth with prodigious violence, throwing up turbid water, the temperature of which was higher than before, and is said to have continued so ever since. The hot baths at Bristol, England, were colored red, and rendered unfit for use, for some time afterward. The waters of Lake Ontario were violently agitated at the same time."

The *space* over which the vibration of the earth is felt during earthquakes, is often very great, but generally more extended in one direction than another; "and where a succession of earthquakes has taken place in the same districts, it is observed, that the noise and shock approach from the same quarter." Although earthquakes are more common in volcanic districts than in others, yet the shocks are not the most violent in the vicinity of volcanos. And, on the contrary, they are stronger in the more distant part of a volcanic country. The ground, generally, is agitated with greater force, as the surface has a smaller number of apertures communicating with the interior.—Extensive earthquakes are sometimes attended by volcanic action simultaneously in various parts of the earth, which seems to indicate a cause deep seated, and of such a nature as to be capable of transmitting the vibrations and pressure, from one portion of the earth to another with great rapidity.

"The *frequency* of earthquakes at particular periods, is worthy of notice. In the 4th and 5th centuries, some of the most civilized parts of the world were almost desolated by these awful visitations. Thrace, Asia Minor and

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Are arthquakes ever felt over extensive portions of the globe? Are the shocks as violent in volcanic districts as in others? Have earthquakes been more frequent at particular periods than at others?

Syria, according to cotemporary historians, suffer
severely: the earth was agitated continually for
riods, and flames were seen to burst forth from th
over a vast extent of surface. On the 26th of J
A. D. 447, subterranean thunders were heard fr
Black to the Red Sea, and the earth was convulse
out intermission for the space of six months: in
places the air seemed to be on fire—towns and larg
of ground were swallowed up in Phrygia. On t
of May, A. D. 520, the city of Antioch was overtu
a dreadful earthquake, and 250,000 of its inhabita
said to have been crushed in its ruins. A raging
vered the ground on which the city was built, and
trict around, spreading over an extent of forty-tw
in diameter, and a surface of 1400 square miles."

"About the middle of the last century, after the
quake at Lisbon, in 1755, Europe, Africa and A
were for some time repeatedly agitated by subte
explosions. Mount Ætna, which had been in a
profound repose for eighty years, broke out with g
tivity; and, according to Humboldt, some of th
tremendous earthquakes and volcanic eruptions
corded in history, were witnessed in Mexico. In th
of the 19th of September, 1759, a vast volcano br
in a lofty cultivated plain," in Mexico. A tract of
about 4 miles square swelled up like a bladder to a
of 524 feet, and in the centre of a thousand burnin
six large masses elevated themselves, forming hil
than 1200 feet in height. The most elevated of th
mountains is 1695 feet high, and is known as the
of Jorullo.*

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*During an earthquake in 1822, 100 miles in length of
coast of Chili, in South America, was raised from 3 to
bove its former level. The whole space from the sea to th
tains was raised, and the interior more than the coast. T
evidences of its having been successively raised, at differ
ods before the one just mentioned. The temple of Sera
originally built near the sea-shore. During an earthquak
so that 24 feet from the bases of the columns was unde
Succeeding earthquakes have raised it, so that the pav
now only about one foot under water.

"More recently (in 1812) the tremendous earthquakes in Caraccas were followed by an eruption in the Island of St. Vincents, from a volcano that had not been burning since the year 1718, and violent oscillations of the ground were felt, both in the islands and on the coasts of America." It was at this time that earthquakes were so violent in the valley of the Mississippi.

"In very violent earthquakes, the secondary strata are broken or agitated, but proofs are not wanting of lesser vibrations being stopped by their pressure. Humboldt says, he has seen workmen hasten from the mines of Marienburg in Saxony, alarmed by agitations of the earth that were not felt at the surface. During the earthquake of Lisbon, the miners in Derbyshire felt the rocks move and heard noises which were scarcely perceived by those above. That an expansive force acting from beneath is the proximate cause of earthquakes, can scarcely be denied; and the prodigious power of steam, when suddenly generated, seems equal to their production, if the quantity be sufficiently great. The great power of steam at high temperatures is well known, and there can be no difficulty in admitting, that, if a current of subterranean water were to find access to a mass of lava many miles in extent, and most intensely heated, it would produce an earthquake more or less violent, in proportion to the quantity of steam generated, and its distance from the surface." Coal mines are sometimes blown up in consequence of the mixture of carbureted hydrogen gas and air, coming in contact with the miner's lamp. Hundreds of lives are thus sometimes destroyed by a single explosion, the mine becoming an immense piece of artillery, and every object in and near the shaft is thrown out with prodigious violence. The force of the explosion is so great as to shake the ground like an earthquake for miles around. The miner will al-

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In violent earthquakes, are the strata ever broken? Are shocks ever perceived below the surface that are not felt by those on the surface? What is supposed to produce earthquakes? What effects are produced by the explosion of coal mines? Who was the inventor of the safety lamp?

ways feel grateful to Sir Humphrey Davy, the inventor of the safety lamp. This is a lamp covered by a frame of wire gauze, through which the flame cannot communicate, so as to explode the gas on its exterior. The miner can now penetrate a work in the mine, where, before, it would have been certain death to approach.

"The horrid crash, like the rattling of carriages, which precedes earthquakes, may be occasioned by the rending of the rocks, or parting of the strata, through which the confined vapor is working a passage." That the rising and falling of the earth during earthquakes is not imaginary, is demonstrated by the facts observed on the sea-shore. The water is often seen to recede far from the shore and then return with redoubled violence. This effect is produced by the rising of the earth, which causes the waters to flow off, and on its sinking again, they return in high, ridgy, overwhelming waves. When Lisbon was destroyed, the return wave was fifty feet in height.

"Volcanos are openings made in the earth's surface by internal fires: they regularly, or at intervals, throw out smoke, vapor, flame, large stones, sand, and melted stone called lava. Some volcanos throw out torrents of mud and boiling water. Volcanos most frequently exist in the vicinity of the sea or large lakes, and also break out from unfathomable depths below the surface, and form new islands and reefs of rock. When a volcano breaks out in a new situation, it is preceded by violent earthquakes, the heated surface of the ground frequently swells and heaves up, until a fissure or rent is formed, sometimes of vast extent. Through this opening, masses of rock, with flame, smoke and lava, are thrown out and choke up part of the passage and confine the eruption to one or more apertures, round which conical hills or mountains are for-

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What is the safety lamp? What is its use? What causes the cracking, rumbling noise before earthquakes? What evidence have we that the earth actually rises and falls during an earthquake? What are volcanos? What do they eject? How are most volcanos located in relation to the sea? By what is volcanic action preceded?

ned. The concavity in the centre is called the crater" and is shaped like a bowl or funnel, shelving steeply down rom the edge to the bottom. "The indications of an approaching eruption from a dormant volcano, are, an increase of smoke from the summit, which sometimes rises o a vast height branching in the form of a pine tree.—Tremendous explosions, like the firing of artillery, commence after the increase of smoke, and are succeeded by ed colored flames * and showers of stones. At length, he lava flows out from the top of the crater, or breaks out rom fissures in the sides of the mountain, and covers the neighboring plains with melted matter, which, becoming onsolidated, forms a stony mass, often not less than some hundred square miles in extent, and several yards in thickness. The eruption of lava has been known to continue everal months. Intensely black clouds, composed of a kind of dark colored sand or powder, improperly called ashes, are thrown out of the crater after the lava ceases o flow, and sometimes involve the surrounding country n total darkness at noonday. Towards the conclusion, the olor of the volcanic sand changes to white: it consists of pumice in a finely comminuted state." During an erupion of Ætna, a space of 150 miles in circuit was covered with a layer of volcanic sand 12 feet deep. "When he lava flows freely, the earthquakes and explosions become less violent; which proves that they were occasioned by the confinement of the erupted matter, both gaseous and solid. The smoke and vapor of volcanos are highly electrical. The quantity of lava thrown out during a ingle eruption of a volcano, seems almost incredible to hose who have not observed volcanic countries. Kircher, n 1660, says, the ejections of Mount Ætna would, if col-

What is the crater of a volcano? What are the indications of an approaching eruption from a dormant volcano? What are the appearances and effects of an eruption? Is the quantity of ejected matter ever very great?

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*The flame of volcanos, as it has been called, is found to be the REFLECTION OF LIGHT from the lava and heated materials, on the *clouds of dust and vapors* evolved during the eruption.

lected, form a mass twenty times as large as the mountain itself; and a few years afterwards, viz. in 1669, the same mountain covered with a fresh current of lava 84 square miles; and again, in 1775, according to Dolomieu, the same volcano poured out another stream of lava 12 miles in length, 1½ in breadth, and 200 feet deep." Hence it is evident, that the seat of the fire is not in the mountain itself, but deep in the earth: the volcano is not the furnace, but the chimney; and it will be necessary to bear this in mind, if we would form an adequate idea of the extensive effects of volcanic action. During the eruption of Skapta Jokul in Iceland, in 1783, two immense lava currents were discharged, one 40, the other 50 miles in length, averaging 11 miles in breadth, and 50 feet in thickness.

" The most extraordinary volcanic eruption recorded in history, for the extent of its effects, took place in Sumbawa, one of the Molucca Islands, in April, 1815. This eruption extended perceptible evidences of its existence over the whole of the Molucca Islands, over Java, a considerable portion of Celebes, Sumatra and Borneo, to a a circumference of a thousand statute miles from its centre, by tremulous motions and the report of explosions; while within the range of its more immediate activity, embracing a space of 300 miles around, it produced the most astonishing effects, and excited the most alarming apprehensions. In Java, at the distance of 300 miles, it seemed to be awfully present. The sky was overcast at noonday with clouds of ashes; the sun was enveloped in an atmosphere, whose palpable density he was unable to penetrate; showers of ashes covered the houses, the streets and the fields, to the depth of several inches; and amid this darkness, explosions were heard at intervals like the report of artillery, or the noise of distant thunder. So fully did the resemblance of the noises to the report of cannon impress the minds of some officers, that from an apprehension of pirates on the coast, vessels were despatched to afford relief. Superstition, on the other hand, was busy at work on the minds of the natives, and attri-

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Is the volcanic mountain the seat of volcanic fire?
Are the explosions of volcanos heard at great distances?

buted the reports to an artillery of a different description to that of pirates. All conceived that the effects experienced might be caused by eruptions of some of the numerous volcanoes on the Island; but no one could have conjectured that the showers of ashes which darkened and covered the ground of the eastern districts of Java, could have proceeded from a mountain in Sumbawa, at the distance of several hundred miles." From Sumbawa to the part of Java where the sound was noticed, is 970 geographical miles. The greatest distance to which the eruption of a volcano had been previously heard, is 600 miles; the explosions of Cotopaxi are sometimes sensibly heard at that distance from the volcano, which is one of the largest and highest on the American continent.

"The long period of repose which sometimes takes place between two eruptions of the same volcano, is particularly remarkable. From the building of Rome to the 79th year of the Christian era, no mention is made of Vesuvius, though it had evidently been in a prior state of activity, as Herculaneum and Pompeii, which were destroyed by the eruption of that year, are paved with lava. From the 12th to the 16th century it remained quiet for nearly 400 years, and the crater was overgrown with lofty trees. The crater was descended by Bracchini, an Italian writer, prior to the great eruption of 1631: the bottom was at that time a vast plain, surrounded with caverns and grottos. Ætna has continued burning since the time of the poet Pindar, with occasional intervals of repose, seldom exceeding 30 or 40 years.

Submarine volcanoes are preceded by a violent boiling and agitation of the water, and by the discharge of volumes of gas and vapor, which take fire and roll in sheets of flame over the surface of the waves. Masses of rock are darted through the water with great violence, and accumulate till they form new islands. Sometimes the crater of the volcano rises out of the sea during an eruption. In 1783, a submarine volcano broke out near Iceland,

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Do volcanos ever remain dormant for any great length of time? By what are submarine volcanos preceded? Are volcanic islands often raised from the sea?

which formed a new island: it raged for several months with great fury, and then sunk and disappeared. Immediately after the volcanic island ceased its action, the great eruption of Skapta Jokul commenced 200 miles distant. In 1811, a small island was formed by a submarine volcano at a little distance from St. Michael's, one of the Azores." It has now sunk, and has 500 feet of water over it. In 1831, a small volcanic island appeared in the Mediteranean Sea, exhibiting various volcanic phenomena, but it has since disappeared, leaving a shoal in its place.* The appearance of new volcanic islands above the ocean is not of rare occurrence: very many such events are recorded in history.

"If the sea, or large lakes, have once covered our continents, it follows, that the greater part of the present and ancient volcanos were once submarine." Many facts indicate that Ætna was once a submarine volcano.

"Volcanos frequently occur in groups, sometimes arranged along a line as if they had originally been formed over one vast chasm. The volcanos in South America, Humboldt observes, instead of being isolated or dispersed in irregular groups, as in Europe, are arranged in rows, like the extinct volcanos of Auvergne, or the volcanos of Java; sometimes in one line, and sometimes in two parallel lines."

There are instances of volcanos having been entirely engulphed in the chasms beneath them. The volcano of the Pic in the Island of Timor, one of the Moluccas, is known to have served as a prodigious watch-light, which was seen at sea at the distance of 300 miles. In the year 1638, the mountain, during a violent eruption, entirely disappeared, and in its place there is now a lake. Many

Do any of the volcanos on the land appear to have been once submarine? Do volcanos occur in groups? How are they frequently arranged? Have volcanic mountains ever sunk into the earth under them?

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* The shoal has now, in 1833, disappeared, and there is a considerable depth of water where the shoal was.

of the circular lakes in the south of Italy are supposed to have been formed by the sinking down of volcanos.

The Papandayang was formerly one of the largest volcanos on the Island of Java, but the greatest part of it was swallowed up in the earth after a short but very severe combustion in 1772. The account of this event says: "Near midnight, between the 11th and 12th of August, there was observed about the mountain an uncommonly luminous cloud, by which it appeared to be completely enveloped. The inhabitants, as well about the fort as on the declivities of the mountain, alarmed by this appearance, betook themselves to flight, but before they could all save themselves the mountain began to give way, and the greatest part of it actually *fell in* and disappeared in the earth. At the same time a tremendous noise was heard, resembling the discharge of the heaviest cannon. It was estimated that an extent of ground of the mountain itself, and its immediate environs, 15 miles long and full 6 broad, was, by this commotion, swallowed up in the bowels of the earth, and about 3000 people perished."

The cause of the conical form so common to volcanic mountains must be obvious to all, who are acquainted with the circumstances attending an eruption. When the expansion or pressure has rent the superincumbent rocks, the liquid lava boils up through the fissures that offer the least resistance, and as it approaches the surface, discharges enormous bubbles of elastic fluids, which project into the air showers of red hot stones, lava and rocks, torn from the sides of the fissures through which they pass. This ejected matter falling, accumulates around the opening in a circular bank, which continues to increase by the fresh addition of materials, until finally it forms a hill or mountain, with a deep cavity in its centre. This cavity, called the crater, is sometimes several miles in extent. Immense volumes of aqueous vapors are evolved from the crater during an eruption, and even for a long

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Explain the cause of the conical form of volcanic mountains. What vapors are most abundantly evolved from volcanos?

time after the discharge of the lava and scorias have ceased. These vapors are condensed in the cool atmosphere, and heavy rains are produced. The lightning darts amidst the clouds, and the thunder peals as if in mockery of the louder thunders of the volcano. The heavy rains falling on a surface thickly covered with the fine ashes and loose scoriae, sweep them along in a flood of mud and stones; this often does more mischief than the lava or earthquakes, and sometimes covers a considerable extent of country. This mud frequently concretes into a light kind of rock which is much used in building wide arches, on account of its lightness and strength. The volcanos in the Andes are said to throw out water and mud more frequently than lava. The deluge of water does not always come from the interior of the earth, but sometimes from the snow on the summit of the mountain being rapidly dissolved. Interior cavities of vast extent and depth are sometimes opened during an eruption, and the water with which they were filled coming in contact with ignited lava is forcibly driven out; and, according to Humboldt, carries along with it a large quantity of small fishes.—These fishes are of the same species that inhabit the neighboring brooks and lakes: the number thrown out is often so great that their putrefaction contaminates the air, and occasions serious maladies among the inhabitants of the adjacent country.

The muddy eruptions of the Andes cover large tracts of country with a bituminous inflammable material, which is used by the inhabitants for fuel. It is called *moya.*

Boiling and hot springs must be classed with volcanic phenomena. They are most common in volcanic districts. The Geysers of Iceland, which throw up hot water to a considerable height in the air, are well known.

Hot springs are common in some parts of Europe, and

What effects are produced by the rapid condensation of these vapors? Do volcanos ever throw out mud and water? Does the water ever contain fishes? Are they similar to those of the adjacent lakes? What is moya? Are boiling springs classed with volcanic phenomena?

in some places the heat is applied to various economical purposes, as for warming houses, hatching eggs, &c.

Hot springs have been observed in several places in the United States. In Arkansas, on the Washita river, a considerable number of these springs break out from the side of a hill, and in a ravine between two hills. They are about 70 in number, and vary in their temperature from 90 to 140 degrees, Fahrenheit's thermometer.

There are very many evidences that volcanic action has been far more active in former periods of time than at present. "The craters of many ancient volcanos are of far greater extent than the present ones. Vesuvius is a comparatively small cone, raised within the crater of a larger volcano. The cone of the Peak of Teneriffe stands within a volcanic plain containing 96 square miles of surface, surrounded by perpendicular precipices and mountains which were the border of the ancient crater." All these craters, according to M. Humboldt, are diminutive apertures, compared with the immense chasms through which, in remote ages, subterranean fire has forced a passage through the crust of the globe. Many of the ancient volcanic rocks have not flowed in currents from limited apertures like modern lavas. "The volcanic porphyries on the back of the Cordilleras," says M. Humboldt, "are undoubtedly of igneous origin; but the mode of their formation is not like modern lavas. The action of volcanic fire by an isolated cone or crater of a modern volcano, differs necessarily from the action of this fire, through the fractured crust of the globe." The only hard crystalline rocks forming at the present day are volcanic; and if we trace the connexion that exists between the modern and ancient volcanic rocks, and between the latter and the rocks of trap and porphyry, among the ancient

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Is the heat of hot springs ever employed for useful purposes? Have hot springs been observed in the United States? Where have several been found? Do volcanos appear to have been more active in former times than at present? Do the ancient volcanic rocks appear to have flowed in currents as at present?

rock formations, we shall extend the dominion of fire over a large part of the globe.

Volcanic rocks are principally composed of feldspar and augite, very minutely intermixed, and they vary in their appearance, as one or the other of these minerals predominates. The lavas in which feldspar abounds, have generally a whitish or grayish color, and melt into a white glass: those in which augite predominates are dark colored, and melt into a black glass. Various mineral substances are found imbedded in volcanic rocks or in their fissures, as ores of iron, bitumen, mica, garnet *olivine*, iron pyrites, &c. The different structures of lava, as vitreous, compact, stony and scoriaceous or spongy, depend on the different circumstances attending its cooling. If cooled rapidly, it is vitreous; if slowly, under pressure, it is compact or stony, and the surface of lava currents is generally scoriaceous or spongy. Pumice is a whitish fibrous spongy lava, and so light as to swim on water. Immense quantities of pumice are sometimes thrown up by submarine volcanos. It has been seen floating upon the sea over a space of 300 miles, at a great distance from any known volcanos; and hence it may be inferred, that submarine volcanos sometimes break out at such vast depths under the ocean, that none of their products reach the surface, except such as are lighter than water.

Another product of volcanos is *sulphur*. In the craters of some extinct volcanos, it occurs in great abundance, and is quarried out like stone from a common quarry. The solfa-tara, near Naples, is an example, and various salts are made in them, as alum, sal-ammoniac, &c.

Trachyte is the name given to a whitish volcanic rock, the grains being sometimes very minute, and has then a glistening lustre. It is mostly composed of feldspar, and

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Of what are volcanic rocks composed? Are many mineral substances found in volcanic rocks? Upon what circumstances does the difference in the structure of lava depend? Has pumice ever been found floating far from any known volcanos? What do you infer from this? Where is sulphur found? What is trachyte?

sometimes becomes porphyritic, and sometimes passes into clinkstone.

The volcanic, trap, and primitive rocks, pass into each other by almost insensible shades, and it seems almost impossible to conceive that the same cause which has produced one, has not also produced the other; but at different times and under different circumstances.

CHAP. XIV.

RECAPITULATION OF THE PRINCIPAL FACTS OF GEOLOGY, AND A SLIGHT DISCUSSION OF SOME THEORIES.

1. The earth's surface is composed of various layers of sand, clay, and rock, and various mixtures of these.

2. Rock is found at a depth varying at different places, but after the solid rock is once reached, it continues as far as the power of man has enabled him to penetrate.

3. There are many kinds of rock, each having its peculiar characters.

4. These rocks have particular positions in regard to each other, so that when several occur together, they lie one over the other in a certain order, which is never inverted.

5. Rocks sometimes alternate with each other, and then they are repeated in the same order in each successive series.

6. The layers of rocks are not always level, but are

Do the trap and volcanic rocks pass into each other? And do these graduate into the primitive rocks? What consequences seem to follow? Of what is the earth's surface composed? Is rock always found below the surface? Are there many kinds of rock? Have they particular positions in regard to each other? Do they ever alternate? Are the layers always level?

often more or less inclined; and often they are nearly vertical.

7. The layers are not always plane, but sometimes present a curved and bent form.

8. Horizontal layers of rock sometimes rest or lie upon those that are inclined, but the reverse is not observed.

9. The strata of rock often present the appearance of having been cracked through like ice, and the fissures filled up with stony matter, by which the rocks are again cemented together.

10. Veins containing the same minerals, generally traverse the rocks in particular districts in the same direction.

11. Several sets of veins are sometimes observed in the same rocks, each set having its particular minerals, and by their intersections, the relative ages of each may be determined.

12. In the vicinity of these veins, fissures, faults, and dykes, the rocky masses often appear to have been moved from their original position. They seem to have been tilted in a direction different from the mass with which they have been connected, or to have slipped down to a lower level.

13. The stony material of the veins and dykes is sometimes of the same kind as the rock, but frequently it is different, and sometimes is composed of metallic ores.

14. There are two great classes of rocks distinct from each other in their characters. One is composed of mineral substances more or less crystalline in their texture, and never contains the remains of animals or plants imbedded

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Are they always plane? Do horizontal layers ever rest upon inclined ones? Is the reverse observed? Do the strata appear to have been cracked through and cemented together again? Do particular veins follow particular directions? Is more than one set of veins ever observed in the same rock? What appearance is observed near veins, faults, dykes, &c.? Is the stony material of veins always different from the rock thro' which it passes? How many great classes of rock occur? How are they distinguished from each other?

in its mass; the other is composed of fragments and comminuted parts of the first, of sand, gravel, or clay, aggregated and cemented together, containing sometimes wood, various remains of animals and plants, or of limestone, which is often almost entirely composed of shells and the remains of various marine animals.

15. The rocks containing the remains of animals and plants, always lie over those that do not contain them.

16. There are many rocks containing organic remains, and each of the series of formations of these rocks, is characterized by certain groups of fossils, as well as by its mineralogical characters.

17. The fossils imbedded in the rocks lying lowest in the series, are almost entirely different from any now known to exist in our seas, or on our islands or continents.

18. The fossil organic remains imbedded in the rocks which lie higher in the series, approximate more towards existing species, and in the rocks of more recent origin, many of the species are similar, and perhaps identical, to species known to be in existence.

19. The rocky strata generally have their outcrop parallel to the principal mountain range, and they slope off from it on each side.

20. Certain minerals are almost constantly associated with certain other minerals, or in particular rocks, so that if some of them be found, the others may probably be found by search.

21. Volcanic agency has been often exerted to raise enormous masses of minerals and rocks from a lower to a higher level, sometimes in a fluid form as lava, and some-

What is the position of the fossiliferous rocks with regard to those which are not so? Do many of the rocks contain fossils? and how are they characterized? How do the fossils in the lowest rocks containing them, compare with those now existing? How is it in the more recent rocks? What is the general direction of the outcrop of strata? Are certain minerals associated with each other? Has volcanic agency ever been exerted to raise islands and mountains?

times in the solid state, as volcanic islands and mountains, and even large tracts of country.

22. Many parts of the surface of our planet, has been repeatedly deluged by eruptions of lava.

23. Volcanos of the present time rarely produce as compact lavas as formerly.

24. Volcanos are now nearly inactive, in comparison with their former state.

25. The temperature from the surface of the earth to a depth of from 20 to 60 feet, is variable from the effect of the seasons and the filtering of spring water, but below that the temperature is constant at the same point.

26. The temperature of the earth is variable at different places at equal depths, but it constantly increases in intensity as we descend farther.

27. This increase of temperature, varies from one to two degrees of Fahrenheit's thermometer, for every 100 feet in depth.

28. The surface of the earth shews that it has been subjected to the action of powerful currents of water, since all the regular rock formations were deposited.

29. In the deposits from this inundation, the remains of innumerable animals, nearly similar to those now existing, were entombed.

30. Local deposits are now forming from the action of rain, streams, currents, winds, and animals, tending to modify and alter the present surface of the earth.

Do any parts of the earth appear to have been repeatedly deluged with lava? How do recent lavas compare with the ancient ones? Are volcanos as active as they were formerly? Is the temperature of the earth variable near its surface? To what depth? From what causes? Is it variable at equal depths in different places? At the same point, how does the temperature compare at different times? As you descend further into the earth, how do the temperatures compare? How much does the temperature increase? What does the surface of the earth shew? What are found in the deposits of this inundation? Are local deposits now orming?

These are some of the principal facts upon which geology rests as a science. Geology is a science of facts, and has no necessary connection with any of the various theories, which have been brought forward at different times to account for the formation of the earth. Those theories were framed by their authors after having observed a few facts, and then giving a free course to their imaginations to carry them to their results.

Theories are useful to the progress of any science, by condensing facts, and by producing an accumulation of them "for the purposes of support or attack."—*Cleaveland's Mineralogy*, p. 719.

There are two theories that agitated the scientific world for some time, and which ought not to be passed over in silence. They are *founded* on facts which are not to be misunderstood. Geologists do not admit either of them to the exclusion of the other, but adopt such parts of each, as are supported by established facts and strong probabilities. The reader has seen that fire and water are the active agents in producing changes upon the earth's surface at present. It was owing to a difference of opinion among geologists, as to whether caloric, or water, was *formerly* the agent causing the changes which are indicated by the various geological phenomena, that these two theories, the Huttonian and Wernerian, were formed. They are also frequently called the Vulcanian and Neptunian theories.

Before proceeding to the theories themselves, it may be well to mention some points upon which they depend, and which are supported by the strongest evidence.

1. "The minerals, which compose the external crust of

From what causes has geology any necessary connection with theory? Of what use are theories? Have any particular theories excited much discussion? Are they founded on facts? Do geologists admit either of them fully? What parts of them are admitted? What causes are now effecting changes upon the earth's surface? What gave rise to the two theories referred to? What are they called? What appears to have been the state of the materials of the earth at some former period?

the globe, from the summit of the highest mountain to the lowest point hitherto explored, must, at some former period, have been in a fluid state; and the solvent, must, unquestionably, have been caloric, or water."

2. "The distinctly crystalline structure of most of the primitive rocks, and the numerous regular crystals which they contain, decidedly indicate a previous state of fluidity."

3. "The numerous organic remains, which exist in secondary rocks, unquestionably prove, that such rocks have been deposited from water. It is well known, that different sorts of secondary rocks have been deposited at different periods. And it is equally evident, from an inspection of the organic remains in secondary rocks, that this ancient sea was *successively* peopled by different races of animals."—*Cleavland*, 722.

WERNERIAN THEORY.

"At some former period this globe has, for a long time, been covered with water to a greater depth, than the original altitude of the highest mountains. This immense body of water was then tranquil, or very nearly so, and contained in solution all the materials of which the present crust of the globe is composed. In this state, chemical deposits, exhibiting more or less of a crystalline structure, were gradually made, and invested the nucleus of the globe. These chemical deposits constitute the *primitive rocks*, consisting of granite, gneiss, mica slate, granular limestone, &c. and are distinguished by their crystalline structure, and by the total absence of organic remains. During this period, most of the highest mountains were formed; for their summits consist of primitive rocks. But, by a gradual subsidence of the waters, the summits of the

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What is the structure of the primitive rocks? What are found in the secondary rocks? What does the fact prove? Were these rocks deposited at different periods? Does the sea appear to have been peopled by different races in succession? What is the Wernerian theory?

:mountains were left naked; the tranquillity of the
was disturbed, and currents were consequently
ed. By these currents, the naked rocks would be
nd partially disintegrated; and the grains or frag-
thus produced, would be diffused through the mass
er. The rocks formed at this period, would, of
consist partly of chemical and partly of mechan-
posits. They would also lie over the primitive
but, in consequence of the diminished altitude of
ters, they would appear at a *lower* level, often res-
the declivities of primitive mountains. Many of
ks of this period contain organic remains of ma-
nimals and marine plants.

organic remains make their first appearance in the
f this period, it is supposed, that the rocky shores,
had recently emerged from the great deep, were
g to a habitable state. Hence this class embraces
re called *transition* rocks, consisting of graywacke,
arieties of limestone, greenstone, argillite, &c.

the level of the great ocean still continuing to sink,
xtensive portions of the earth were left exposed to
reasing violence of the currents, and the solution
was originally chemical, now became in a great
composed of grains or comminuted fragments, de-
from the older rocks. Hence the minerals of this
consist chiefly of mechanical deposits. They lie
e two preceding classes, but still appear at a *lower*
n consequence of a greater subsidence of the wa-
Hence, also, they are found near the base of high
ains, or in hills of moderate height, or in vallies, or
plains, sometimes at a great distance below the
surface. This class is composed of the secondary
and embraces sandstone, most varieties of compact
ne and of gypsum, chalk, basalt, some varieties of
tone, coal, &c.

tensive portions of the crust of the globe had now
e dry: new species and genera of animals inhabit-
waters, or dwelt on the land, while numerous ve-
es adorned the shores and other parts of the earth's
. Hence the secondary rocks abound with organic
s, both of animals and vegetables. Hence, also,

the abundance of bituminous substances in this class, having proceeded from the decay of organized bodies.—There are a few exceptions to the general fact concerning the *low level*, at which the secondary rocks usually appear; for they sometimes rest on the summits of mountains highly elevated. Basalt and wacke are among the secondary rocks thus found. These elevated strata of secondary rocks are supposed by Werner to have been deposited during a second and sudden rise of the ocean, after it had once greatly subsided. The preceding deposits of rocks are supposed to have been universal formations, "like the coats of an onion. But various subsequent revolutions and changes, have, in many instances, destroyed or concealed the continuity of strata. This universality in the formations of rocks, is an important point in this system. Two other classes of comparatively small extent, viz: alluvial deposits and volcanic ejections, complete the series of mineral formations."—*Cleaveland*, p. 723.

HUTTONIAN THEORY.

"In the theory of Dr. Hutton, *caloric* constitutes the most important agent. This theory supposes the solid crust of the present globe, to have proceeded from the disintegration and destruction of former continents by the gradual action of the atmosphere and water—that the ruins of those ancient continents were transported by water, and deposited at the bottom of the ancient seas—and that these heterogeneous materials, thus deposited, were consolidated by the action of subterraneous fire; and, by the same agent, were subsequently elevated to form the present continents. It further supposes, that gneiss and other stratified rocks, were only softened, elevated, and sometimes variously inclined, while granite and other unstratified minerals were completely fused, and, in many cases, forced upward by this powerful agent through the superincumbent strata. Hence we find granitic summits surrounded by gneiss, mica slate, &c. Hence, also, metallic veins were filled from below by injections of melted

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Give the Huttonian theory.

matter. By a similar process, this theory provides for the disintegration and partial destruction of existing mountains and continents, and for their transportation to the bottom of present oceans, from which, by the action of subterraneous fire, they are again to be raised and constitute new and future continents."—*Cleaveland*, p. 726.

The Wernerian theory is, in many parts, founded on a close observation of facts; but it is so interwoven with hypothetical points, which are not confirmed by succeeding observations in other parts of the world, that it cannot be received. It is not all true, and it does not account for all the facts.

The Huttonian theory consists of inferences drawn from facts, but the deductions are sometimes carried farther than the facts warrant. It supposes the present continents derived from the wrecks of older ones, because, we find a large portion of the rocks upon the surface of the earth formed of the fragments of others cemented together, and often filled with the remains of animals that once inhabited the sea. But whether volcanic agency has caused those lands to be elevated, whic[illegible]ve evidently been for a long period under the surface of the ocean, is a point which is not conceded by all. It is however rendered highly probable by some facts which have been mentioned under the head of volcanos and earthquakes. The Huttonian theory supposes the secondary rocks, after they were formed in the bed of the ocean, to have been indurated by subterranean heat, before they were raised to become islands and continents. Some experiments by Sir James Hall, which have been already mentioned, render this supposition probable.

The Huttonian theory supposes the earth to have once been in a melted state, and to have cooled gradually.

Is the Wernerian theory founded on facts? Are his theoretical conclusions confirmed? Are the deductions of the Huttonian theory carried farther than facts warrant? Are his deductions rendered highly probable? What justifies the conclusion that the earth has been in a melted state?

The phenomena of volcanos and veins, and the constantly increasing temperature observed in penetrating below the surface, seem to justify the conclusion that the earth has been fluid, and that it still may be so at a considerable depth below its surface.

Since the discovery by Sir Humphrey Davy that the alkalies and the earths are metallic oxides, some have supposed the interior of the earth to be a mass of the earthy and alkaline metals. Many of these metals when in contact with water decompose it, and burn with the evolution of intense heat. Large quantities of gaseous matter and vapor are produced. If the waters of the ocean were to filter through the fissures of the rocks and come in contact with such materials as many suppose to constitute the interior of the earth, intense heat would be evolved, the materials would be melted, if they were not so already, highly elastic vapors and gases would be formed in immense quantities, and all the phenomena of volcanos and earthquakes would be produced. The effects would account for most of the facts observed, as in metallic and other veins, dislocation, obliquity, contortion of strata, &c.

In concluding this sketch of geology, it may not be amiss to give Prof. Silliman's views of volcanic phenomena, and they are also applicable to the explanation of most geological facts. His views are not entirely original, but have been extended much beyond the suggestions which led to them.

"The act of creative energy, admitted alike by religion and philosophy, necessarily implies the production of all the elements of which our physical universe is composed. How far these elements were originally united in binary, ternary, or still more complex combinations, we cannot possibly know. The revelation of this fact, not being necessary to our moral direction, has been withheld by the Creator, and we know only, that, "In the beginning, God created the heavens and the earth." As to the actual

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Of what is the interior of the earth supposed by some to be composed? What would be the theory of volcanic action upon this supposition? Would the effects account for most of the facts of geology?

condition of the elements, at that primeval period, science may fairly enquire, and is justified in reasoning within the limits prescribed by our moral condition and intellectual powers.

"If we suppose that the first condition of the created elements of our planet, was in a state of freedom; the globe being a mass of uncombined combustibles and metals, and that the waters, the atmosphere and chlorine, and iodine, and perhaps hydrogen, were suddenly added; it will be obvious, from what we know of the properties of these elements, that the reaction, awakening energies before dormant, would produce a general and intense ignition, and a combustion of the whole surface of the planet. Potassium, sodium and phosphorus would first blaze, and would immediately communicate the heat necessary to bring on the action between the other metals and combustibles, in relation to the oxygen and chlorine, and in relation to each other. Thus a general conflagration would be the first step in chemical action.

"In this manner might be formed the fixed alkalies, the earths and stones and rocks,—the metallic oxides properly so called,—the sulphurets and phosphurets of the metals,—carburet of iron,—the acids, including the muriatic,—and ultimately, the salts, and chlorides, alkaline, earthy and metallic, and many other compounds resulting either from a primary or secondary action. In such circumstances, there would also be great commotion: steam, vapors and gases would be suddenly evolved in vast quantities, with explosive violence; the imponderable agents, heat, light, electricity and magnetism, and attraction, in various forms, would be active in an inconceivable degree, and the recently oxidized crust of the earth would be torn with violence, producing fissures and caverns, dislocations and contortions, and obliquity of strata; and it would everywhere bear marks of an energy then general, but now only local, and occasional. It is however obvi-

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What are Prof. Silliman's views upon the supposition that the interior of the earth is composed of the alkaline and earthy metals?

vious, that this intense action would set bounds to itself; and that the chemical combinations would cease, when the crust of incombustible matter thus formed, had become sufficiently thick and firm, to protect the metals and combustibles beneath, from the water and air, and other active agents.

"As we are not now giving a theory of the earth, but merely stating the conditions of a problem, we forbear to descant upon many obvious collateral topics, or to pursue the primitive rock formations through the vicissitudes which might have attended them. We do not even say, that we believe that such events as we have attempted to describe, did actually happen; we say only that their existence is consistent with the known properties of the chemical elements, and with the physical laws of our planet. Supposing that such was the actual state of things, it is obvious that the oxidated crust of the globe, would still cover a nucleus, consisting of metallic and inflammable matter. Of course, whenever air and water, or saline and acid fluids, might chance to penetrate to this internal magazine, the same violent action which we have already supposed to have happened upon the surface, would recur, and the confinement and pressure of the incumbent strata, increasing the effects a thousand fold, would necessarily produce the phenomena of earthquakes and volcanos. Still, it is equally obvious, that every recurrence of such events, must oxidize the earth deeper and deeper, and if the point should ever be attained, when water or air ceased to reach the inflammable nucleus, or the nucleus were all oxidized, the phenomena must cease, and every approximation towards this point would render them less frequent.

"Does this correspond with the actual history of these events? Are they now less frequent, than in the early ages of our planet? The extensive regions occupied by rocks of acknowledged igneous origin, but where fire is not now active, would seem to favor this idea; but the answer to this question must depend so much upon the theoretical views entertained of the formation of granite, and of the other primitive rocks, that it may be impossible, at present, to bring it to a decision.

"Whatever we may think of the hypothesis now detailed, may we not suppose, with sufficient probability, that those *voltaic powers* which we *know* to exist—whose action we can command, and whose effects having been first observed within the memory of the present generation, now fills us with astonishment—are constantly active in producing the phenomena of earthquakes and volcanos?

"Arrangements of metals and fluids are the common means by which we evolve this wonderful power, in our laboratories; and it would seem that nothing more than juxta-position, in a certain order, is necessary to the effect. Even substances apparently dry and inert with respect to each other, will produce a permanent, and, in proportion to the means employed, a powerful effect; as in the columns of De Luc and Zamboni. It would seem indeed that metals and fluids are not *necessary* to the effect. Arrangements of almost any substances that are of different natures, will cause the evolution of this power. Whoever has witnessed the overwhelming brilliancy and intense energy of the great galvanic combinations, especially of the deflagrator of Dr. Hare, and considers how very trifling in extent are our largest combinations of apparatus, compared with those natural arrangements of earths, salts, metals and fluids which we know to exist in the earth, in circumstances similar to those, which, in our laboratories, are effectual in causing this power to appear, will not be slow to believe, that it may be in the earth perpetually evolved and perpetually renewed; and now mitigated, suppressed or revived, according to circumstances influencing the particular state of things at particular places. In our laboratories, we see emanating from this source, intense light, irresistible heat, magnetism in great energy, and above all a decomposing power, which commands equally all the elements and proximate principles in all their combinations.

What is said of the effect of the voltaic powers? Are such phenomena produced by the different rocky, earthy and fluid materials of the globe? Would the theory account for most of the observed facts of Geology?

Sir Humphrey Davy, after discovering that the supporters of combustion and the acids, were all evolved at the positive pole, and the combustibles and metals, and their oxidated products, at the negative—proved, that even the firmest rocks and stones could not resist this power, their immediate principles and elements being separated by its energy. The decomposition of the alkalies, earths, and other metallic oxides, being a direct and now familiar effect of voltaic energy—their metals being set at liberty, and being combustible both in air and water—elastic agents produced by this power, and rarified by heat, being also attendant on these decompositions, it would seem that the first principles are fully established by experiment, and that nothing is hypothetical, but the application to the phenomena of earthquakes and volcanos.

"It appears an important recommendation of the present view, that causes are here provided which admit of indefinite continuation, and of unlimited renovation.—There appears no reason why, on the whole, the phenomena should cease, as long as the earth exists. It has therefore the great Newtonian requisites of a good theory; *its principles are true, and it is sufficient.*"—*Silliman's outline in the* 1st *American edition of Bakewell's Geology,* pp. 115—119.

SKETCH

OF THE

History of Geology.

We learn, that the speculative part of Geology, engaged the attention of mankind at a very early period.

The priests of Egypt maintained the aqueous origin of the globe; Thales taught that the solid materials of the Earth were deposited from water; Zeno that fire was the "prima materia," and the Earth formed from it.

In the limited number of physical subjects that engaged the attention of *classical* antiquity, we can include but a few insulated phenomena that come within the limits of Geology.

Such striking natural appearances as earthquakes and volcanoes, could not escape notice, and we find crude theories to account for them in various authors.

The formation of new land by the mud brought down and deposited by rivers, the appearance of new islands in the ocean, and the encroachment of the sea on the land, are not unfrequently mentioned by Pliny, Aristotle, and Strabo.

With one of the great facts of geological investigation and speculation they were also acquainted. This fact, is, that shells, and various other organic remains, occur in immense quantities, embedded in the solid rock, and often at a great depth below the surface; but it seems to have excited little of their attention or curiosity.

It seems singular that this fact, which would have afforded demonstrative evidence of the favorite dogma of some of their schools, that the face of nature was continually changing, and what was now dry land, was once covered by the sea, should have been overlooked.—

Ovid alone, with a view to illustrate the above doctrine, puts into the mouth of Pythagoras, the words,

> "Vidi factas ex æquore terras
> "Et procul a pelago conchæ jacuere marinae."

In some of their physical notions, we perceive the germs of more modern theories, or at least, the theories have been formed from an imperfect observation of similar facts.

The theory adopted and adorned by Buffon, who appears to have considered the displacement of the sea as a periodical revolution of nature ; and the wild but splendid conception embraced by many of the ancient schools, and particularly by the Stoics, that the Earth had experienced frequent destructions and renovations, through the agency of igneous and aqueous devastations, recurring after distant intervals of time, reminds us, in many points, of the Huttonian theory of the Earth.—It seems more consistent, however, with the general tenor of their philosophical speculations, to believe that it was deduced from their high "a priori" principles, rather than from any train of inductive reasoning, founded on observation.

Middle Ages.

In the middle ages, the Arabian writers seem to have cultivated mineralogy with some success.

Tenth Century.

Avicema, at the close of the 10th century, was the fir who laid the foundation of a rational arrangement minerals.

Several Italian writers noticed the appearance of f sil shells in their hills at an early period.

Fifteenth Century.

In the 15th century, Alessandro degli Alessandri, posed the hypothesis, that the axis of the Earth's tion, might, originally, have had a different position the present one, as a means of accounting for the ch in the place of the land and sea.

Sixteenth Century.

castoro, in 1517 enters at large into a discussion of nd having been covered by water, and he arrives at nclusion, that the phenomena are such as cannot be ined by a transient convulsion, such as the deluge

change in the axis of the Earth, found an advo- n more recent times in Voltaire, who believed in the radition of the Egyptians, that the sun had twice n the west within the memory of that nation, and ed this, to a revolution of the Earth's axis around its equatorial diameters, which he imagined was eted in 4,000,000 years.

however needless to add, that astronomical observ- does not afford the slightest ground for these specu- ; the real change in the obliquity of the ecliptic confined within very narrow limits, is inadequate ount for any geological phenomena.

rge Agricola, who flourished during the first half 16th century, published on several branches of alogy, and he illustrated in a full, precise, and clear r, the various phenomena of metalic veins.

re the close of the 16th century, George Owen, an hman, left behind him a valuable manuscript work topography of his native county. In this, we e earliest attempt to establish the important and nental geological fact, that the same series of ucceed each other in a regular order, through ex- tracts of country; but his work having remained uscript until recently, shows us a striking instance e anticipations of subsequent discoveries, which e often observed in the history of science, but can- ve contributed in any degree to their advancement.

Seventeenth Century.

ing the 17th century, we find little but theoretical without observation, as Burnet, or collectors with- neral views; but Llwydd, appears to have been ly acquainted with the fact, that particular shells n particular strata.

Lister, demands our attention, as the first proposer of regular geological maps. The very idea of this proposal, shews an acquaintance with the regularity of geological structure, occurring over extensive districts. Another important observation in relation to him, is, that he was, in at least one instance, led to the distinction of *strata*, by their organic remains.

Eighteenth Century.

Woodward's essay on the natural history of the Earth in 1702, was the first thing published in England that contained any important geological facts.

The discourses of Hooke on earthquakes in 1705, the physico theological discourses of Ray in 1713, and the new theory of the Earth by Whiston in 1722, were chiefly of a speculative nature. In 1723 we find the arrangement of the strata in regular zones, described by Holloway (Phil. Trans.) and by Mr. Packe in 1730; and about the same time Strachey, described the coal district of Somersetshire, and he observed the inclined position of the coal strata and the horizontal superincumbent rocks. Strachey was also acquainted with the regular succession of strata.

Towards the middle of the 18th century, the scattered rays of information are seen beginning to converge into a stronger and more steady light, and to approximate to a regular system.

In 1740, DeMaillet, who had long resided in Egypt, adopted the opinions of the ancient philosophers, and having seen the waters by their earthy depositions contribute to the extension and formation of land, he attempted a general explanation of the formation of the Earth.

In 1746, Guettard first executed the idea proposed by Lister years before, of geological maps, but by attempting too much, he brought his method into disrepute.

Lehman in 1756 was the first to establish firmly the great distinctions between the primitive and secondary rocks.

In 1760, the Rev. J. Mitchell, in a paper on the cause and phenomena of earthquakes, gave the whole doctrine of the regular succession of the stratified masses, constituting the crust of the Earth, and he observes that this structure is such, that we may always meet with successive zones of the various mineral masses, lying parallel to, and rising towards the principal mountain range,

Fuchsel, a German writer, made known that certain rocks were not only characterized by their mineralogical structure, but by their organic remains, in two works he published in 1762 and 1775. He determined the relative positions of many of the rocks. His theoretical geology is remarkable, and far superior to that of Werner, which was afterwards so generally adopted. *See Dela Beche, p.* 181.

In 1778, Whitehurst's enquiring into the original state of the Earth, although mostly theoretical and speculative, contained some good observations on the geological structure of some parts of England.

James Douglass, in 1785, published a dissertation on the antiquity of the Earth, in which some organic remains were particularly considered.

In 1788, Hutton published his theory of the Earth, and this is a work which has exerted a lasting influence over geologists. Hutton has the merit of having first directed the attention of geologists to the important fact of granite veins issuing apparently from beds and strata of granite, and traversing all the surrounding rocks.

He also brought forward in a striking manner, the circumstances that seem to shew the igneous origin of the trap rocks; but the wildness of some of his theoretical views, may well go to counterbalance the utility of the facts he gathered from observation.

Werner published his researches in 1787, but his system seems to have received accessions until 1796. It is difficult to estimate his independent and real merits, as he never published much of his system; we are informed of it only through his pupils. His principal merits seem to have been in a superior acquaintance with the mineralogical characters of rocks, in having traced with minuteness the primitive, transition, and secondary rocks, in that part of Germany, and in reducing the hitherto irregular elements of geological science, into a more strict and systematic form. His *theory* must *now* appear to almost all, as among the most unphilosophical and unsuccessful yet framed, and his few remaining adherents are one by one abandoning his most characteristic opinions.

There appears to have been in the character of Werner a concentration of all his powers to the advancement of his favorite pursuit, and his zeal was communicated to all his pupils. Werner, has, by his popularity, and the spirit of enquiry he set on foot, probably done more for the advancement of Geology, than any other individual, and he has, perhaps properly, been called, the *Father of the science*.

The travels of Saussure in the Alps, afforded important contributions to geological science, and Pallas, in his mineralogical surveys of the Russian Empire, has noted many important geological facts.

In 1790, Mr. Wm. Smith, a mining engineer, commenced his geological researches, and in a few years published local maps of a considerable portion of England. His labors have done more to advance this science in England, than those of any other individual, and by many he is supposed to have done as much for it as Werner.

Since the commencement of the 19th century, more materials have been collected to forward the science of Geology than had been before. A numerous and able class of geologists have arisen since that time in England, and another in France, and the United States have produced some. The principal of the English Geologists are, Buckland, De La Beche, Conybeare, Phillips, Murchinson, Lyell, Grenough, Bakewell, Parkinson, Webster, Sedgewick, McCulloch, Taylor, Fox and Elie de Beaumont.

Among the French geologists who have done most, may be mentioned Cuvier, the Brongniarts, (father and son,) Boue, De Luc, and Saussure.

In Germany, De Buch, Raumer, Ebel, Keferstein, and many others in various parts of Europe might be mentioned.

In the United States, Maclure, Silliman, Hitchcock, Morton, Eaton, James, Hayden, Olmstead, Cleaveland, Cist, Webster, and some others have been active in developing the geology of the United States.

Mr.Maclure and Gen. S. Van Renssalear, deserve notice particularly; the first for his great geological survey of the United States, and his munificent donations to the various scientific societies, of rare and valuable books; the other for his liberality in causing a minute geological survey of the State of New York and part of the adjoining States, to be made at his expense.—These two men have given an impulse to the science, that must result in the developement of the geology and resources of this country.

Before geology ranked as a science, the efforts of the early speculators were directed to the wild and ample region of pure theory, connected with the origin of the globe; the connection of scriptural history with physical events, and the traces and effects of the Noachian deluge.

The descriptive part of geology was then a blank.—For their soaring views, it would have appeared beneath the dignity of science to classify rocks and minerals, or descend into a minute comparison of the organic remains entombed in the rocky strata, with the existing species.—Why should they, to whom nature had revealed her ample page, scrutinize the "modus operandi," which, they imagined, would add little to a knowledge of general facts or laws? Why should the phenomena of active causes be minutely examined, the destructive influence of volcanoes and earthquakes, or the devastating operations of seas, and rivers, and torrents, when a *comet* might so easily in imagination be summoned to scorch the Earth from pole to pole, and by its attraction submerge the continents and change the axis. No dynamical effect was too great for such resources.—As new phenomena arose, new underplots were added to the drama of creation, and so remained until by new discoveries, new substitutions were rendered necessary. An advancing state of physical science, led men to correct the laxity which the theories of the formation of the Earth had assumed, in the time of Burnet and Whiston, Werner and Hutton, both of whom gave much weight to the fact of observation, raised a new and very superior class of geologists. Whatever may have been the errors of their theories, it is certain that their influence on the minds of men has been of much importance in causing the advance of the science. Hutton's doctrine of the consolidation of earthy materials by heat and pressure, and Werner's theory of universal formations, were brought to the tests of experiment and observation. The one was confirmed more satisfactorily than could have been expected under factitious circumstances; the other was shewn to have originated in its utmost generality in the narrow views of its ingenious but untravelled author. One was passed by in silent neglect, the other attracted crowds of disciples from all parts of Europe. The former of these men died when his theory had hardly attracted notice, the latter, in the full career of glory. Like the fabled Phenix, Hutton's theory arose from his ashes, but from the time Werner was laid in his grave, his was found wanting in the generality which he had assigned it.

The acrimony, which the controversy between the disciples of these two men produced, caused a reaction, and geologists resolved for a time to banish hypotheses, and, unbiassed by theory, endeavor to view nature as she is; and thus, men have become habituated to using well their hands and eyes, and amassing facts before theorizing.

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ERRATA.

The reader is requested to make the following corrections with his pen.

Page 5th, 10th line from the top, after geography, insert *which*.
" 6th, 14th do. for point, read *part*.
" 8th, 9th do. for heavier, read *greater*.
" 8th, 10th and 11th do. erase the *commas* after *near* and *earth*.

Page 9th, 1st line at top, for volcanoes, read *volcanos*.
" 12th, 4th and 5th lines from the top, for substance is, read *substances are*.

Page 12th, 11th line from the bottom, for and, read *land*.
" 15th, 13th line from the top, for thourand, read *thousand*.
" 15th, 8th line from the bottom, after whole, insert *number*.
" 25th, 16th line from the top, for silex, read silica.
" 27th, 9th do. for there appears, read *here appear*.

Page 28th, 13th line from the bottom, for silex, read *silica*.
" 33d, 9th do. for laminar, read *laminæ*.
" 44th, 6th line from the top, for others, read *other*.
" 45th, 10th line from the bottom, insert *therefore* after rocks.

Page 45th, 11th line from the bottom, erase *fossils of the*.
" 47th 9th line from the top, for slate, read *slates*.
" 54th, 13th do. after the quotation, write *Eaton's Geology*.

Page 56th, 14th line from the bottom, for magnesium, read *magnesia*.

Page 57th, 6th line from the top, the same.

" 58th, 7th line from the bottom, for springs, read *openings.*

" 63d, 16th line from the top, erase *iron ore.*

" 64th, 18th and 20th do. for minerological, read *mineralogical.*

Page 67th, 22d line from the top, for shews, read *shew.*

" 67th, 10th line from the bottom, for monle, read *monte.*

" 70th, 10th line from the top, for west, read *north.*

" 75th, 10th do. for for levelling, read *level.*

" 76th, 12th do. for phenomena, read *phenomenon.*

Page 82d, 10th do. for firey, read *fiery.*

" 89th, 22d do. erase *And.*

" 89th, 4th line from the bottom, for arthquakes, read *earthquakes.*

Page 94th, 4th line from the top, for Dolomica, read *Dolomieu.*

" 104th, 3d do. for has, read *have.*

" 113th, 26th do. for laboratortes, read *laboratories.*

Page 121st, 8th do. for Renssalear, read *Rensselaer.*

'W c y

[illegible]

O. HAMPI

O. hampé

[illegible]

The salt of the ocean if separated would cover the earth to the depth of 1800 ft

The mean depth of the ocean is estimated at 10 miles

[illegible]

+ [illegible] of ocean beds

[illegible]

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